NILE'S EARTH 2023

INTERNATIONAL CONFERENCE

STUDY AND CONSERVATION OF EARTHEN ARCHAEOLOGICAL SITES IN ANCIENT EGYPT AND SUDAN

PROCEEDINGS - MARCH 2024

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INTERNATIONAL CONFERENCE
4-5-6 JULY 2023

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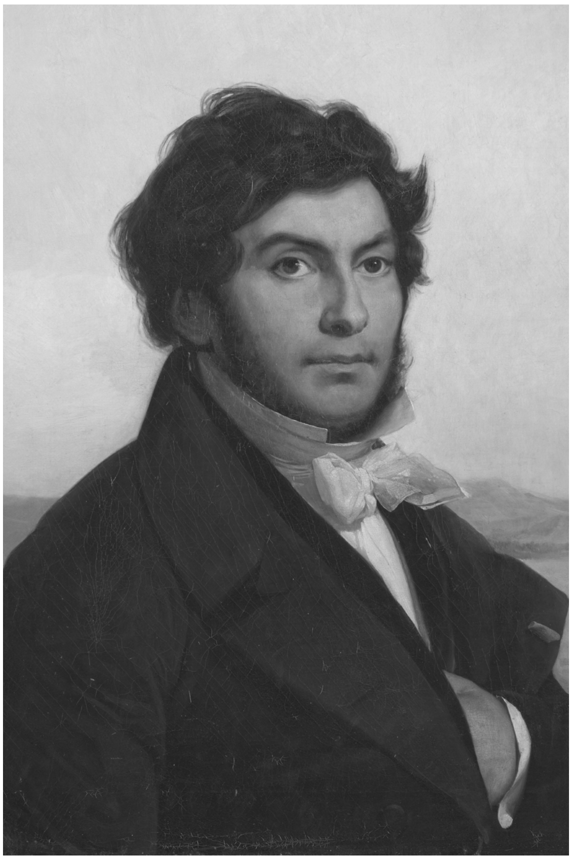
TRIBUTE TO

The Nile's conference has taken place two hundred years after the decipherment of the ancient hieroglyphs by Jean-François Champollion who studied in Grenoble transmitting to our people in Grenoble (more specifically than elsewhere) a passion for the Nile Valley and its treasures.

Besides that, CRAterre creation by the end of the 1970s has been very much inspired by the vision and architectural achievement of the world-known Egyptian Architect Hassan Fathy.

This conference and its proceedings are dedicated to their memory!

JEAN-FRANÇOIS CHAMPOLLION



Portrait of Jean-François Champollion by Léon Cogniet.
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HASSAN FATHY

Hassan Fathy in Cairo by Dimitri Papadimos.
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ACKNOWLEDGMENTS

The Nile's Earth 2023 conference could not have been such a success without the involvement of numerous organizations and dedicated persons.

We would therefore like to acknowledge the contributions of:

- The members of the Organization Committee, with special thanks to Alix HUBERT and Audrey CARBONNELLE;

- The members of the Scientific Committee, with special recognition to Fekri HASSAN, Anthony CROSBY and Jeffrey SPENCER for their strong involvement in the preparation of the Nile's Earth 2023 Declaration and for editing the articles with the authors;

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- The overall staff of IUGA, and more specifically the technical staff in charge of the auditorium, venue of the conference;

- The overall staff at IFAO, and more specifically those who organized the broadcast of the conference on their premises in Cairo, making it possible for a larger number of colleagues from Egypt and Sudan to attend;

- Our colleagues who accepted to be session moderators: Ahmed Al TAHER, Julie ANDERSON, Anthony CROSBY, Bérangère REDON, David GANDREAU, Thierry JOFFROY, Nadia LICITRA, Séverine MARCHI and Bakonirina RAKOTOMAMONJY;

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- The ANR for funding the Nile's Earth Programme (ANR-21-CE27-0019) and, as such the Nile's Earth 2023 Conference, making possible the participation / contribution of IFAO, CFTEEK, SFDAS, UMR 8167 (Orient et Mediterranée) and UMR 5189 (HISOMA);

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- ALIPH, which made a substantial contribution that enabled the participation of Sudanese colleagues and which also financed some of the projects presented during the conference, as well as the presence of a representative, Mr. Adonis El HUSSEIN;

- UNESCO, for honoring our conference with the presence of Ms. Youmna TABET at the opening ceremony;

- ICOMOS ISCEAH, with the presence of Mrs. Maddalena ACHENZA, chairperson of ISCEAH at the opening ceremony and who also contributed with a paper;

- The Ministries of Culture of Egypt and Sudan, and in particular their specialized bodies: MoTA and NCAM;

- All conference participants who passionately contributed through the presentation of papers, posters and during discussions, including via videoconferencing.

TABLE OF CONTENTS

OPENING SPEECHES 9

WELCOME WORDS / Thierry JOFFROY 10

THE GENERAL DIRECTOR OF NATIONAL CORPORATION FOR ANTIQUITIES AND MUSEUMS, SUDAN / Prof. Ibrahim MUSA 12

THE CO-DIRECTOR OF CENTRE FRANCO-ÉGYPTIEN POUR L'ÉTUDE DES TEMPLES DE KARNAK, EGYPT / Ahmed Mahmoud Taher MOHAMED 13

THE CHAIRPERSON OF THE INTERNATIONAL SCIENTIFIC COMMITTEE FOR EARTHEN ARCHITECTURAL HERITAGE ICOMOS / Maddalena ACHENZA 15

UNESCO WORLD HERITAGE CENTRE / Youmna TABET 18

NILE'S EARTH 2023 DECLARATION 23

THEME 1: ARCHAEOLOGY, ARCHITECTURE AND BUILDING CULTURES 27

THE ORIGIN AND EARLY DEVELOPMENT OF CASEMATE ARCHITECTURE IN EGYPT / Peter LACOVARA 28

NILE MUD-BRICK ARCHITECTURE AS SEEN IN THE CALOTYPES OF FÉLIX TEYNARD / Nathalie KAYSER-LIENHARD 34

MUDBRICK ARCHITECTURE FROM THE AVENUE OF SPHINX. AN OVERVIEW ON THE BUILDINGS' TECHNIQUES FROM TRENCH 4 AT SECTOR 5 / Ahmed ALTAHER 41

ANOTHER BRICK IN THE WALL: FIRST ARCHITECTURAL RESULTS OF THE STUDY ON DENDARA'S WALLS / Matthieu VANPEENE 50

MUD-BRICK STRUCTURES AT ABUSIR CENTRE. TRADITION, STRATEGIES, USAGE / Jaromír KREJČÍ 58

THE ARCHITECTURAL DESIGN OF NEWLY DISCOVERED POTTERY AND LIME KILNS AT TABBET METAWAH SITE, WEST ALEXANDRIA / Mohga ABD EL-KAWY 67

THE ARCHITECTURE OF THE ANIMAL CATACOMBS IN DENDARA / Sylvain DHENNIN 74

TESTIMONIES OF COOPERATIVE CARE: A SOCIOECONOMIC SYSTEM OF MAINTENANCE OF THE OLDEST MOSQUE IN SUDAN / Tomomi FUSHIYA, Mohamed HASSAN SIEDAHMED 81

DIALOGUE BETWEEN TWO SITES: THE EXPERIENCE OF PROTECTING THE EARTHEN GREAT WALL IN CHINA / Yujia FAN 89

DOCUMENTING EARTHEN CONSTRUCTION PROCESSES AND TECHNIQUES. CASE STUDY OF KSAR TIMIMOUN, ALGERIA / Haroune BEN CHARIF, Azeddine BELAKEHAL 96

LAST TESTIMONIES OF EARTHEN ARCHITECTURE IN ORIGINAL COMMUNITIES OF TARAPACÁ, CHILE / Jenniffer QUIROZ BRAVO 104

THE EARTHEN ARCHITECTURE OF HASSAN FATHY OR HOW ARCHITECTURE CAN CONTRIBUTE TO THE PRESERVATION OF THE NILE'S HERITAGE / Zineb BENNOUNA 111

THEME 2: RAW AND BUILDING MATERIALS **121**

FIRST INSIGHTS INTO THE EARTHEN ARCHITECTURE OF THE SITE OF PLINTHINE / Clément VENTON, Maël CRÉPY, Bérangère REDON 122

EVALUATION TABLE OF ANCIENT EARTHEN BUILDING MATERIALS / Fikriye Pelin KURTUL-VACEK 129

STRUCTURAL ASSESSMENT OF MOSQUE BUILDING IN OLD DONGOLA, SUDAN / Wojciech TERLIKOWSKI, Martyna GREGORIOU-SZCZEPANIAK, Ewa SOBCZYŃSKA, Kacper WASILEWSKI 137

FROM THE SILT TO THE SHALE CLAY, FROM THE VALLEY TO THE DESERT: THE MATERIAL TRANSFORMATIONS OF THE RED BRICK AND ITS SUPPLY CHAIN IN EGYPT AND SUDAN / Corten PÉREZ-HOUIS 143

CONSOLIDATION OF ADOBE BRICKS FROM THE CHURCH AT MISEEDA. BIOCALCIFICATION OF ADOBE, BASED ON A BIO-BASED LIQUID IMPREGNATION SYSTEM / Karel INNEMÉE, Henk JONKERS, Yask KULSHRESHTHA, Sylwia SVOROVÁ PAWEŁKOWICZ, Olga SYTA, Dobrochna ZIELIŃSKA 150

THEME 3: CONSERVATION, VALORISATION AND MANAGEMENT **157**

EXCAVATION TO CONSERVATION, THE MUD BRICK PYRAMID OF TETISHERI / Anthony CROSBY, Ayman Mohamed DAMARANY 158

CONSERVATION OF THE EARTHEN ARCHITECTURAL ASSETS AT PEPY I NECROPOLIS ARCHAEOLOGICAL SITE: HOW TO ADAPT TO CLIMATE CHANGE? / Thierry JOFFROY, Xavier HÉNAFF 165

BARAKA: REVITALIZATION OF SUDAN'S OLDEST PRESERVED MOSQUE AT OLD DONGOLA. CONSERVATION OF THE WALL PAINTINGS, PROJECT ASSUMPTIONS AND PRELIMINARY TEST RESULTS / Magdalena SKARŻYŃSKA, Krzysztof CHMIELEWSKI 173

MAINTENANCE AND RESTORATION OF MUD AND MUD-BRICK BUILDINGS: KHANDAQ TOWN AS A CASE STUDY / Admed Hussein Abdelrahman ADAM 181

COMMUNITY ENGAGEMENT IN EARTHEN HERITAGE CONSERVATION IN THE WESTERN DESERT IN EGYPT / Shaimaa FOUAD ELSHISHTAWY 190

MITIGATION AND ADAPTATION TO CLIMATE CHANGE IN THE CONSERVATION AND PRESERVATION OF THE ARCHITECTURE AND FUNERAL LANDSCAPE IN QUBBET EL HAWA, ASWAN, EGYPT / Dolores JOYANES-DÍAZ, Carmen MUÑOZ-GONZÁLEZ 197

ŠĪR-DARWĀZA HISTORIC WALL: AN ARCHITECTURAL AND HISTORIC STUDY FOLLOWED BY A CONSERVATION PROPOSAL / Sayed Mossadeq KHALILI 204

CONSTRUCTION DETAILS AGAINST MOISTURE IN ANCIENT BABYLON AND ITS SURROUNDINGS / Maddalena ACHENZA, Ammar AL TAEE 213

THEMATIC WORKSHOPS **221**

ÉLÉMENTERRE PEDAGOGICAL KIT 222

FIELD TESTS FOR CONSERVATION WORK 223

BIOGRAPHIES **225**

CONFERENCE COMMITTEES **231**

ORGANISATION COMMITTEE 232

SCIENTIFIC COMMITTEE 233

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OPENING SPEECHES

WELCOME WORDS

THIERRY JOFFROY
Architect-Research director (HDR)
Deputy director of AE&CC research unit
Director CRAterre research team
ENSAG / UGA

The Representative of the Agence Nationale de la Recherche, Dr. Marine Lechenault,
The Representative of UNESCO World Heritage Centre, Ms. Youmna Tabet,
The Chairperson of ISCEAH, Ms. Maddalena Achenza,
The Director General of NCAM, Prof. Ibrahim Musa,
The co-Director of CFTEEK, Dr. Ahmed Mahmoud Taher Mohamed,
Dear colleagues, dear participants,

Bonjour, Good morning, Al-salam aleikoum,

On behalf of Ms. Marie Wozniak, Director of ENSAG, the school of architecture of Grenoble University, it is a real pleasure for me to welcome all of you to the Nile's Earth conference, the first of its kind with an international scope.

On a more personal note, let me thank all of you for the interest you have shown in such an initiative. Today we are a bit more than 90 present in this auditorium, and we have about 20 colleagues present at IFAO in Cairo, while for various reasons 20 additional colleagues are participating in a remote position. But why discussing issues related to the Nile Valley in Grenoble?

In the short introductory text inside the program, I have referred to the two hundred years anniversary of the decipherment of the ancient hieroglyphs by Champollion who actually studied in our University here in Grenoble. So actually in Grenoble, probably more than elsewhere in the world, we have had for long a special relationship with the Nile valley: a kind of passion.

But more than that, Nubian traditional architecture and the works of the famous Egyptian architect Hassan Fathy have been paramount in inspiring the creation of CRAterre in 1979. Of course the first inspiration, in the 1970s of the group of students of our school who created it was the earthen architectural heritage in our region, known as *Pisé* architecture. But one of the founder did work in Soudan in the same period, while one of the international initiatory journeys of this group was in southern Egypt, where Hassan Fathy himself was met and many archaeological sites and settlements were visited. This journey in Egypt was a real inspiration and since that, the idea of inspiring from traditional as well as ancient cultures has remained in our daily reflections, it is even one of the main reason for the specific structure of our research program along three axis: Heritages, Materials and Habitats.

Actually, the concept that is driving our forces today is that of linking study and conservation of heritage to contemporary architectural production. This is applied in various context, and what is impprtant to us is to make sure that we don't forget all good knowledge that can be learnt from heritage all over the world.

This inspiration partly received from Hassan Fathy and the heritage in Nubia represents for us quite a debt to the Nile Valley. Thus, when we have been contacted some years ago to be assisting in some efforts to conserve some archaeological sites along the Nile valley, we did accept.

First activity was in Sudan, at Saï Island in 2007 within the Africa 2009 program undertaken with ICCROM and UNESCO.
In 2010, one of our colleague participated in the mission organized by UNESCO at New Gourna, the famous village built by Hassan Fathy for taking stock of its preoccupying state of conservation.
Later on in 2016, a mission was undertaken at the Ramesseum at Thebes west, under the direction of Christian Leblanc.
Further, in 2019, a new demand came in from Nadia Licitra of Orient et Méditerranée at Sorbonne University, to work at the Treasury of Shabaka in Karnak in Luxor.
This later was a start of a reflection leaded by both CRAterre and UMR 8167, Orient & Méditerranée directed by Pierre Tallet, further shared with the other partners of the project, which led to the idea of enlarging the scope and proposing a project to ANR in response to its annual call for project.

The second attempt did succeed making possible the Nile's Earth Project, which is the overall framework within which this conference is organized. The idea of this program is rooted in the observation that, since the birth of Egyptology in the nineteenth century and then Sudanology, the interest of researchers has focused mostly on stone architecture. The earthen architecture that is however much older and also systematically associated with it has been rather poorly studied and even less preserved nor enhanced, though with few monumental exceptions. But in recent years, it has become clear that there is a need to better take into account these vestiges of earthen architectures for ensuring a full understanding and proper restitution to both research and the general public. Some first attempts have been conducted by teams of archaeologists, but with results that are not always satisfactory. In addition to that, it appears that earthen heritage of the ancient Nile Valley is increasingly threatened by current climate and ecological changes (e.g., heavy rains, dam construction, and cultivation of previously semi-desert or desert areas, soil salinization). Thus it is today recognized that specific solutions are needed to effectively preserve Egyptian and Sudanese archaeological sites.

In that context the ANR Nile's Earth project was designed with the aim to contribute to that quest through exploring the potential of multidisciplinary approaches for a better identification and knowledge of these archaeological earthen remains, the assessment of their state of conservation, and the definition of adapted and sustainable conservation methods and techniques.

The assumption is that, to be relevant, conservation protocols must rely on a thorough knowledge of ancient building techniques and materials, as well as the original building culture. To undertake that, a literature review is being carried out while a series of specific case studies (8) are taken as reference with for some of them attempts to develop a methodological approach towards adequate conservation interventions.

Still, a major activity of this project is what we start today: the Nile's Earth 2023 International Conference. Its aim is to stimulate an international debate towards better characterizing the earthen architecture of the ancient Nile Valley. It also aims at better identifying needs and exploring relevant methodologies and solutions to meet the growing demand for adequate conservation and enhancement of Egyptian and Sudanese archaeological sites, in accordance with international recommendations. Thanks to all of you present today for the interest that you have shown in our initiative, I'm quite convinced that we will collectively be able to achieve that.

But before we start, I would like to recognize the hard work of both the organizing committee and the scientific committee, but also of ENSAG and IUGA staff we have helped us establishing favorable conditions for making this event successful. That also applies to all the colleagues at IFAO in Cairo where participation is also possible through the broadcasting system put in place. A regret is that this could not be done also at SFDAS in Khartoum, but let's hope that the situation there will soon improve and we will make sure that professionals from Soudan will be able to benefit from this conference and its outputs.

As a final acknowledgement, I would like to thank more specifically the ANR for funding this project, all the partners to the project for their inputs, and also ALIPH for the assistance given to participation of our Sudanese colleagues, and also to all the special guests that we receive today. It is really an honor to have you with us.

Welcome to Grenoble! Welcome to Nile's Earth 2023 that, hopefully, will be the first of a long series!

THE GENERAL DIRECTOR OF NATIONAL CORPORATION FOR ANTIQUITIES AND MUSEUMS, SUDAN

PROF. IBRAHIM MUSA
General director of NCAM, Sudan
from Ifao, Cairo, Egypt

Bismillah ar-Rahman ar-Rahim.

Wassalatu wassalamu ala rasulillah al-kareem.

Ladies and gentlemen, very good morning to all of you.

It gives me great pleasure to be with you this morning on the occasion of such an important conference.

Earthen architecture in the Middle Nile region has two important dimensions: the first is its extensive temporal dimension, spanning more than 6,000 years, from Western Defuffa of Kerma and the Meroitic Palace of Natikamani, through the Middle Ages and up to the present day.

The second is its geographical scope: earthen architecture is widespread throughout Sudan, north and south, east and west. These two elements make it one of the most important factors that have built Sudanese identity and the development of indigenous knowledge for building and architecture that deserves to be studied in greater depth, and this conference provides us a very good opportunity for this.

Ladies and Gentlemen, on behalf of myself and my colleagues, I would like to express our gratitude and appreciation to the conference organizers for their efforts in preparing this conference and for inviting us to participate.

I would also like to thank all the speakers, colleagues and friends taking part in this conference.

I wish you full success in all your endeavors.

Thank you very much.

Choukran djazilan.

THE CO-DIRECTOR OF CENTRE FRANCO-ÉGYPTIEN POUR L'ÉTUDE DES TEMPLES DE KARNAK, EGYPT

AHMED MAHMOUD TAHER MOHAMED
Co-Director of CFTEEK, Egypt

The Deputy Director (HDR) of AE&CC research unit and Director of CRAterre research team, Dr. Thierry Joffroy,
The Representative of the Agence Nationale de la Recherche, Dr. Marine Lechenault,
The Representative of UNESCO World Heritage Centre, Ms. Youmna Tabet,
The Chairperson of ISCEAH, Ms. Maddalena Achenza,
The Director General of NCAM, Prof. Ibrahim Musa,
Dear colleagues, dear participants,

Al-salam aleikoum, Bonjour, Good morning,

I am pleased to be with you today to participate in this conference, which I believe is aimed at preserving one of the most important forms of urban heritage, not in the Nile Valley, but perhaps in the world.

It was also my pleasure to hear from Arch. Joffroy this ancient interest in the architectural heritage of the Nile Valley and to express my particular pleasure at the simulation of the earthen architecture of the Nile valley here at Grenoble.

There is no doubt that the human heritage in the Nile Valley is something to be proud of. The special nature of this earthen heritage requires us to constantly think about ways to preserve it for future generations.

The earthen architecture in the Nile Valley represents an important source of information on the history of this civilization. We have mud brick temples and tombs, administrative buildings and forts, houses and chapels.

From here comes the idea of this conference to find the best methods on how to study, record and conserve these buildings. It is undoubtedly an idea that deserves all our support and that we spare no effort in providing all means of success for it. In the end, we are all responsible for leaving this cultural legacy to our successors in the best way possible.

Preserving this heritage needs us to understand good Building techniques and Building history of earthen architecture, its origins, evolutions, functions and uses.

We also need to strengthen our knowledge of Raw and Building materials side by side with Conservation, Valorization, Management and community engagement and these are the main themes of this conference.

I see that we need more studies in this regard, and perhaps this conference is a good opportunity for us to tell the specialists about that. We want to intensify our efforts in circulating the case studies that will be presented in the conference sessions to all Nile Valley sites.

Especially with the issue of climate change, which is one of the issues that preoccupied and still preoccupies the Egyptian official thought. Egypt was keen to host the recent climate conference.

Egypt also took serious steps to implement a sustainable development model, with climate change and adaptation to its effects at the heart of it, and aims to reach 50% of government-funded green projects by 2025 and 100% by 2030.

There is a general orientation in Egypt now towards green architecture. Similar to what Hassan Fathi did in West Luxor and several other places in Egypt, some institutions are now simulating the mud-brick architecture in the Nile Valley. Everyone knows the benefits this architecture represents for the environment and people.

Therefore, we need to go deeper into understanding the earthen heritage of the Nile valley, which is what this conference seeks to achieve.

There is a clear impact on the heritage of the Nile Valley due to climatic changes, and there is no doubt that the mud-brick architecture will be more affected than others by this change. Hence, the importance of events aimed at preserving the earthen heritage of the Nile valley.

Therefor Egypt called for the need to support the African continent with a special treatment within the framework of implementing the Paris Agreement, given its special situation and the magnitude of the challenges it faces. We must not forget that the Nile Valley contains a heritage that strongly testifies to the history of human's on earth.

Ladies and Gentlemen,

I am confident that the various activities that our conference will witness and the results that will come out of it will reflect the best ways to preserve this earthen heritage. I am also confident that this will reach all those interested in the topics on the agenda of the conference, so that this conference will be a motivator for everyone who is preoccupied with this heritage. I would also like to express our support for the Nile earth project and the reports that will be issued on it. There is no doubt that everyone's goal is to find the best ways to understand, record and preserve the huge earthen heritage.

Thank you and I wish a productive conference for everyone.

THE CHAIRPERSON OF THE INTERNATIONAL SCIENTIFIC COMMITTEE FOR EARTHEN ARCHITECTURAL HERITAGE ICOMOS

MADDALENA ACHENZA
ICOMOS-ISCEAH

It is with great pleasure that I participate to the opening of the important meeting Nile's Earth focusing on earthen architecture in ancient Egypt and Sudan.

ISCEAH, the ICOMOS International Committee for the Study and Conservation of Earthen Architecture, that I here represent, supports the event considering it strategic for the conservation and study of earthen architecture in the Nile valley in particular, but also for the contribution to the research on the field altogether.

In 1987, the first ISCEAH, the ICOMOS International Committee for the Study and Conservation of Earthen Architecture was founded, following four ICOMOS-supported international scientific symposia on earthen architecture (held in 1972, 1976, 1980, and 1983). By the time of the ninth international symposium in Yazd, Iran, the Committee became inactive and was dissolved in 2004. ISCEAH, International Scientific Committee on Earthen Architectural Heritage in its current form, was founded in 2005. Elections were held, with John Hurd chosen as President (UK, 2005-2014), and Pamela Jerome as Vice-President. Since then, Julio Vargas Neumann (Peru, 2015-2017), Mariana Correia (Portugal, 2018-2020) and Maddalena Achenza (Italy, 2021-2023) were the following Presidents of ISCEAH.

The committee is composed at present of near 140 members divided in Expert, Associate, non-ICOMOS members, and Emerging Professionals.

Of them, only 14 members come from the Africa Continent. Members can apply to 5 different subthemes: Archaeology, In-Use, Technology, Seismic and Landscapes that propose specific activities of research and documentation.

One of the main events associated with the Earthen Committee is the Terra World Congress. Terra events started as small gatherings:
- International Colloquiums (1972 -Yazd, Iran; 1976 - Yazd, Iran);
- International Symposia (1980 - Ankara, Turkey; 1983 - Lima and Cuzco, Peru);
- International Meeting of experts (1987 - Rome, Italy);

and developed into International Conferences (*Adobe 90*, Las Cruces, NM, USA; *Terra 93*, Silves, Portugal; *Terra 2000*, Devon, UK; *Terra 2003*, Yazd, Iran; *Terra 2008*, Bamako, Mali; *Terra 2012*, Lima, Peru);
to turn to World Congresses (*Terra 2016*, Lyon, France; *Terra 2022*, Santa Fe, NM, USA;
The next Terra Congress is expected to be in Cuenca, Ecuador in 2025.

Terra events have always had a positive impact on the territories where it was organized, consolidating previous activities and introductory to new ones.

General interest and specialized participation have grown internationally in the past years, frame-working concerted actions for preservation of earthen architecture, as well as the establishment of networks, associations, and entities for its protection.

ISCEAH, through each sub-committee, aims to contribute to the international debate around earthen architecture broadly considered. During the very past years the Committee focused on different tasks, such as:
- Guidelines for Conservation Practice (In-Use sub-committee);
- Glossary of Earthen Materials Deterioration Patterns (Archaeology sub-committee);
- Review and translation of the Earthen Cultural Landscape concept and questionnaire (Landscape sub-committee);
- Glossary in Technology (Technology sub-committee);
- Post-earthquake assessment research and earthquake mitigation: guidance on what to do and what not to do after an earthquake (Seismic sub-committee).

ISCEAH has also developed and co-organized several international activities. Despite the World Congresses, ISCEAH promoted online inter ICOMOS Scientific Committee webinars and conferences, contributed to the Exhibition of Earthen Architecture in the Arab States; regularly revises nominations for the World Heritage Fund; established focal working groups for Climate Change, Heritage Impact Assessment + COVID-19 impact, Sustainable Development Goals, Human rights.

In response to the ICOMOS mandate for Emerging Professionals (EPs) in ISCs, ISCEAH approved 10 new members to the Emerging Professionals Working Group. Of these, four are currently ISCEAH Board members. ISCEAH EPWG members contribute to the Committee operating transversal overall research and feeding new energy towards innovative practices and views.

During the current mandate, ISCEAH has committed in working on the recognition of rural heritage sites and their associated tangible and intangible values acknowledging that old settlements represent the backbone of any country - places where people live differently from large cities, often with better quality of life and a more human scale. They are places of contemplation and slowness, well represented by the craftwork of artisans, by high quality agriculture, and by the protection of biodiversity. These concepts require protection, awareness, and support, to make living in peripheral places more attractive.

For this reason, the Committee has been tackling several issues that include the dissemination of earthen architectural heritage's intrinsic significance. This involves raising communities' awareness and understanding on the value of the earthen heritage, so that the same communities apply monitoring and appropriate maintenance.

The use of technology (photogrammetry, 3D models, digital reconstruction) in recording earthen architectural heritage has allowed an effective and efficient diagnosis of damage, allowing a planned strategy for intervention, protecting the integrity and authenticity of earthen World Heritage. Digitalization becomes a powerful resource for awareness raising, and ISCEAH could have a more dynamic approach in this regard. The accelerated progress of tools and techniques for data collection raises the potential for better information management, along with dissemination through multimedia and publications, having a positive impact on conservation and protection of cultural heritage internationally.

In response to climatic change, there has been growing demand for ecological and sustainable construction. Lessons from earthen architecture hold great value, reducing the carbon footprint through rehabilitation and construction.

Universities and the 41 members of the UNITWIN network of the UNESCO Chair of Earthen Architecture, Building Cultures and Sustainable Development, as well as PROTERRA, the Iberian-American network of earthen architecture and construction, with its 131 individual and institutional members, are engaged in the dissemination of scientific and technical knowledge of earthen architecture. Several members of these networks are also ISCEAH members.

Strengthening the connection of ISCEAH with other networks and entities - as the UNESCO Chair on earthen architecture, PROTERRA, the GCI Earthen Architecture Initiative - could help address a more sustainable international approach, also reinforcing collaborations between IS researchers and professionals in different regions of the world.

Nevertheless, more incisive efforts need to be addressed to tackle the gap in knowledge regarding guidance for earthen architectural heritage conservation.

For this reason, ISCEAH has begun developing a Charter for Earthen Architectural Heritage. This is a demanding task that will be carried out with consistency, inclusiveness and reasonableness.

Moreover, the In-Use sub-committee is creating Guidelines for earthen architecture that will address technical knowledge, specific activities, and methods of conservation.

The Charter and the Guidelines will instruct professionals and non-professionals throughout the conservation and rehabilitation of historic earthen heritage.

ISCEAH, with its considerable work done in the field of earthen architectural heritage through over 35 years remains an international repository for the field's technical expertise and know-how.

In a historical period when increasing urbanization and growing climate change concerns are shifting the focus from rapid construction towards more sustainable methods, ISCEAH has a new opportunity to apply lessons learnt from earthen architectural heritage to steer a virtuous development of earthen architecture.

To effectively do this, ISCEAH will need to expand its capacity-building efforts to different audiences, guarantee its presence on all the continents, and provide targeted specialized training.

With strong persuasion ISCEAH shares CRAterre's effort to spread knowledge and sensitization in the field, with the awareness that even an event focused on a specific region can help to acknowledge the power that heritage conservation has in strengthening people's identities and preserving building cultures worldwide.

UNESCO
WORLD HERITAGE CENTRE

YOUMNA TABET
UNESCO World Heritage Centre

Dear Director of the International Centre for Earthen Construction,
Dear Directors, dear Chairperson,
Dear colleagues,
Ladies and Gentlemen,

Good morning,

First, I would like to warmly thank the École Nationale Supérieure d'Architecture de Grenoble and the International Centre for Earthen Construction, CRAterre, for organizing this important international conference.

At this occasion, let me convey the best wishes of the Director of World Heritage at UNESCO, Lazare Eloundou Assomo, who would have been delighted to be with us today and to participate in the debates on the conservation of earthen architecture in Ancient Nile valley.

The region that we are examining is rich of thousands of archaeological sites, some of them are very well-known, many more are less known, thus the importance of carrying a project for an enhanced knowledge and improved conservation in this area.

We are glad that this conference will shed light on several very interesting sites in Egypt and in Sudan, which are testimonies of the very ancient civilizations that prospered along the Nile.

We are most sorry that at the same time, in Sudan, our colleagues are facing distressing events that put cultural heritage at risk. UNESCO is closely monitoring the situation, and devising with its partners and stakeholders, an emergency response to support the preservation of Sudanese cultural heritage.

The journey in Egypt and Sudan was a real inspiration for the creation of CRAterre, as Thierry Joffroy recalled, well, let me tell you how important the Nile Valley is for UNESCO and the history of World Heritage preservation.

In 1954, the decision to build the Aswan High Dam would lead to the creation of a huge artificial lake covering the Upper Nile Valley from Aswan in Egypt to the Dal Cataract in Sudan – a culturally extremely rich area known as Nubia since antiquity.

Following the request from Egypt and Sudan in 1959, UNESCO launched an appeal for an International Campaign to Save the Monuments of Nubia. This appeal resulted in the excavation and recording of hundreds of sites, the recovery of thousands of objects, and the salvage and relocation of a number of important temples to higher ground, the most famous of them being the temples of Abu Simbel and Philae.

The success of the Campaign inspired the development and adoption in 1972 of UNESCO's World Heritage Convention and the inscription of sites on UNESCO's World Heritage List.

The Arab States region is very rich in World Heritage earthen sites, or World Heritage sites that incorporate earthen construction work. If we look at the World Heritage list today, they are 26 sites with earthen architecture over 90 properties in the region, including 60% of them in North Africa. To name few: The Old City of Ghadames in Libya, Bahla fort in Oman, Ksar of Ait-Ben-Haddou in Morocco, or Ashur (Qalat Sherqat) in Iraq.

In Egypt, New Gourna Village is located within the property of Ancient Thebes and its Necropolis inscribed in 1979 on the World Heritage List. Although New Gourna is situated inside the boundary of the property, its outstanding value was not considered in the nomination dossier at the moment of its preparation.

In 2009, UNESCO initiated a project for the safeguarding of this important site. This project is still ongoing, this year we are launching the restauration of a public building.

One of the fundamental goals of the proposed UNESCO initiative is to valorise the pioneering ideas and philosophy of Hassan Fathy's work and to reinforce its relevance to contemporary sustainability concerns. Fathy's philosophy derived from humanistic values about the connections between people and places and the use of traditional knowledge and materials especially the exceptional advantages of earth as full-fledged construction material.

The Tentative List of Egypt and Sudan, which is the inventory of sites that the countries would consider for nomination to the World Heritage List, also have several sites with earthen architecture. For example, the site of Al Khandaq, in Sudan, presents a unique example of mud brick two story high buildings, which housed the rich merchants' families. Enhancing the knowledge about the sites open doors for international recognition and preservation for future generations.

The World Heritage properties must justify outstanding universal value, integrity and authenticity, and have legal and management mechanisms in place to ensure preservation. The earth material is renewed by maintenance. In that case, its authenticity lays in the perpetuation of the traditional materials, shapes and techniques, as well as the associate intangible practices related to its maintenance as it is the case for example, the roughcast of the Timbuktu's Mosques in Mali.

Earthen architecture has a legitimate place on the World Heritage List. It is one of the most original and powerful expressions of our ability to create a built environment with readily available resources. It includes a great variety of structures, ranging from mosques, palaces and granaries, to historic city centres, cultural landscapes and archaeological sites.

Earthen architecture plays a vital role in defining the identity of local communities, involving sustainable building techniques and often conveying true artistic expression.

There is also a growing interest in its ability to contribute to social, ecological and cultural development. The availability and economic quality of the material mean that it bears great potential to contribute to poverty alleviation and sustainable development.

Its cultural importance throughout the world is evident and has led to its consideration as a common heritage of humankind, therefore deserving protection and conservation by the international community. In 2023, over 12% of the World Heritage properties incorporate earthen structures. This represents almost 150 sites worldwide.

However, earthen structures are increasingly threatened by natural and human impacts such as floods and earthquakes, industrialization, urbanization, modern building technologies or disappearance of traditional conservation practices. It deserves particular attention in terms of conservation and maintenance. About 1/3 of the sites inscribed on the World Heritage List in Danger are sites with earthen structures.

Since 1979, CRAterre has been working for the recognition of the earth material in order to meet the challenges related to the environment, to cultural diversity and to the fight against poverty. It has been a major partner of the UNESCO World Heritage Centre in all issues related to the preservation and safeguarding of the earthen heritage.

CRAterre supported many of the activities of the World Heritage Programme on Earthen Architecture (WHEAP) that was active between 2007 and 2017. We can recall the restauration of the Royal Palaces of Abomey in 2015 after fire, the first Inventory for World Heritage Earthen Architecture, that Craterre is currently updating, the rehabilitation et revitalisation de la 'Maison des jeunes' (the youth Center) in the Old Towns of Djenné, also in Mali, among many.

The WHEAP Programme aimed at a better understanding of the problems facing earthen architecture, the development of policies favouring its conservation, the definition of practical guidelines and the organization of training and awareness activities, particularly in local communities to raise the recognition of earthen architecture, as well as the creation of an active global network for the exchange of information and experience.

We are glad to see that this network perpetuates through today's conference.

Our partnership is also crucial for the implementation of the Operational Strategy for Priority Africa 2022-2029, and in particular its flagship programme No 3 related to Cultural Heritage and Capacity Development. This programme aims at supporting Government institutions, experts and communities, including women and youth, in increasing representativity on the World Heritage List and enhancing the protection, conservation, management, safeguarding and promotion of World Heritage, in view of harnessing sustainable livelihoods and development in Africa.

Already CRAterre is involved in supporting the elaboration of nomination files for several countries in Africa that does not have yet a site inscribed on the World Heritage List.

We are grateful for their very active role in the field of Earthen architecture preservation, and we thank them all organizers for this valuable conference.

We are looking forward to receiving its recommendations.

Thank you.

Hawara pyramid, Fayyum oasis, Egypt © T. Joffroy

NILE'S EARTH 2023 DECLARATION

NILE’S EARTH 2023 DECLARATION

The Nile’s Earth 2023 International Conference was held from July 4 through July 6, 2023 in Grenoble, France. Its purposes were: (1) to promote a better understanding of the scope of earthen architecture and archaeological sites in the Nile Valley and (2) to share perspectives on the current state of conservation, and the present and future challenges in protecting this important part of World Heritage for the future. The themes explored were: (1) archaeology, architecture and building culture, (2) raw and building materials, and (3) conservation, site presentation and management.

A total of 32 papers (mostly covering Egypt and Sudan, but with case studies from other countries: Afghanistan, Algeria, China, Chile and Turkiye) were presented to the audience in Grenoble, as well as audiences in Cairo and other locations around the world, including China, Peru, Spain, Turkey and the USA, via electronic media, enabling exchanges and debate amongst a hundred and ten attendees from a variety of disciplines. As a conclusion to the conference, the participants have agreed on the following statement of values and recommendations.

STATEMENT OF VALUES

For more than 6000 years a building culture developed along the Nile Valley that led to numerous and diverse architectural achievements, based on the use of earth, mainly using sundried bricks of different sizes and composition.

This heritage is represented by a wide range of architecture including very large monuments: temple enclosure walls more than 20 m high, pyramids up to 75 m high and massive foundation platforms, as well as humble houses, granaries, workshops, kilns and other everyday structures.

Over such a long period of time, the builders tested numerous innovations, adding knowledge and skills that permitted increasing levels of building sophistication, as revealed by both structural techniques and building details that strived to attain the objective of building for eternity. The building culture also included decoration and delicate architectural features ensuring thermal comfort and well-being.

The building knowledge acquired through the use of these sundried bricks gradually opened the door for later achievements using stone, allowing the construction of prestigious monuments that represent Ancient Egypt to the world. Many of these stone monuments, however, still contained subsidiary elements built with sundried bricks. This culture has been retained to present times in some elements of vernacular architecture, very well adapted to the local resources, climate, means and capacities of local communities.

This overall heritage is an immense resource which deserves to be further explored to improve knowledge of the ancient civilizations of the Nile Valley and inspire architects in their quest for solutions to the challenges of our changing world. The efforts already made by Architect Hassan Fathy by the middle of the 20 th century need to be acknowledged and continued, by ensuring the conservation of his architectural achievements and pursuing the vision he proposed, which is now more relevant than ever.

RECOMMENDATIONS TO ARCHAEOLOGICAL MISSIONS

1. Ensure that earthen structures are taken in consideration with full respect of their values and specific mechanical properties and plan the potential need for conservation measures before, during and after excavations with the involvement of conservation experts.

2. Be systematic in the documentation of past, present, and future archaeological research and conservation projects, with detailed surveys (plans, drawings and photographs) of the structures before and after restoration.

3. Adopt research in the fields of ethnoarchaeology and experimental archaeology, as well as microarchaeology and archaeobotany, as sources of information and understanding on ancient environmental conditions, landscaping practices, together with subsistence, diet and cultural activities.

4. Include a regular research component in projects to identify potential decay factors and processes so that interventions may be identified to address them efficiently or at least with the aim of drastically reducing risks.

5. Identify the need / relevance for temporary protection measures and explore potential adequate responses. These may include, but are not limited to (1) temporary protective shelters, (2) temporary shoring and bracing, (3) backfilling, (4) the elimination or mitigation of threats.

6. Develop protocols for conservation strategies with special attention to the values associated with the site (or specific assets) on one side, and the threats and potential processes of deterioration on the other. The site architecture should be clearly understood prior to the design of the intervention(s).

7. Take care with the use of new technologies by preparing samples that can be evaluated both in terms of technical efficiency and aspect / aesthetic, with special attention to issues related to maintaining authenticity.

8. Adopt the incorporation of training components while also exploring the possibilities of establishing sustainable educational activities and interpretive programmes.

9. Ensure that projects are well documented, including materials, techniques and applied expertise, so that the information can be used later without duplication or repetition of issues that have been previously addressed.

10. Develop integrated management plans, not only for the long-term conservation of earthen sites, but also to encourage and promote interpretation and display of the significance and merits of ancient and traditional earthen architecture to policy makers, local communities, international visitors, professionals and students.

MORE BROADLY, IT IS RECOMMENDED THAT INSTITUTIONS (INTERNATIONAL, NATIONAL, LOCAL) ADDRESS THE FOLLOWING AREAS:

11. Undertaking surveys and documentation of earthen archaeological sites with priority for sites facing the danger of urban expansion, neglect, climate change, and unregulated development.

12. Recording and documenting indigenous terminology used by local communities as well as jargon used by earthen heritage professionals, in order to develop a multilingual glossary of standardised scientific terminology cross-referenced to equivalent vernacular or poorly-defined terms currently in use.

13. Promoting comparative and diachronic investigations to understand further the dynamics of generational change and transformation in the use of materials, techniques, designs and building site organization (including the location of soil quarries, transport of water, sand, and other materials), as well as intercultural exchange of ideas and practices.

14. Standardising methods of field testing and laboratory analysis of earthen materials in accordance with existing standards used in the analysis of sediments, to determine mechanical properties and structural stability, as well as methods used in the display and interpretation of results.

15. Documenting and archiving information related to archaeological and traditional earthen sites, structures, methods, practices, know-how, cultural context and condition in a database accessible to all, including data on the adaptation or reuse of ancient earthen techniques and heritage structures to contemporary needs.

16. Ensuring accessibility of any information placed in archives, documentation centres, or online, while also adding data to the world database on earthen architecture and building techniques.

17. Exploring the potential impact of the use of earthen materials on the environment and the inhabitants of earthen structures and how such architecture impacts on the social fabric of society.

18. Preparing curricula and relevant content to allow development of the teaching of traditional earth building practices, to aid in understanding the complexities of Nile earthen architecture and any appropriate interventions, and to make possible the continuation of this tradition to address today's habitat needs with minimum environmental impact.

19. Promoting this heritage and its potential for addressing some contemporary needs in social media, permanent and travelling exhibitions and other formal and informal avenues using digital visualization, social media applications, and pedagogical kits.

20. Developing and supporting capacity-building programs to sustain traditional knowledge of designing, constructing, maintaining and conserving ancient archaeological and threatened vernacular earthen architectural structures, aimed at local builders and architecture students through short courses, workshops and study tours.

21. Enhancing and strengthening efforts to engage local communities in all conservation and management efforts, with special attention to expanding and ensuring the educational, social and economic benefits to local communities in accordance with Sustainable Development Goals.

22. Organizing regional, national, and international meetings and conferences. In this respect a continuity to Nile's Earth 2023 with similar events every 2 to 4 years is highly anticipated.

This declaration was prepared by Thierry Joffroy, Fekri Hassan, Jeffrey Spencer and Anthony Crosby on the basis of the discussions held during the conference and finalized after being circulated to all participants and then to the scientific committee for validation.

Shunet El Zebib, Abydos, Egypt © T. Joffroy

THEME 1

ARCHAEOLOGY, ARCHITECTURE AND BUILDING CULTURES

THE ORIGIN AND EARLY DEVELOPMENT OF CASEMATE ARCHITECTURE IN EGYPT

PETER LACOVARA
The Ancient Egyptian Heritage and Archaeology Fund

SUMMARY

An interesting facet of Egyptian brick architecture is the construction of rectangular cells or casemates which are filled in to form a foundation.[1] While well-known from numerous examples dating from the New Kingdom to the Greco-Roman Period, its sudden appearance in the Second Intermediate Period has been a matter of conjecture. The earliest appearance of this form of architecture is at the site of Deir el-Ballas in Upper Egypt.[2] The author has previously suggested that the origins of the architectural form lay in the design of the 'great tumuli' at Kerma.[3] This hypothesis has recently been challenged by Natalia Malecka-Drozd who has attempted to find Near Eastern or indigenous Egyptian antecedents for the development of this type of foundation.[4] The purported Near Eastern inspirations center around the defensive gate constructions such as those at Hazor and Ebla.[5] However, these features are stone masonry and not foundations but just infill to create a more substantial bastion.[6] Malecka-Drozd admits that, "there is no example of a proper casemate platform in a Near Eastern building from the Bronze Age,"[7] and seeks to find an Egyptian origin for the technique.

INTRODUCTION

This author has previously suggested that the origins of brick casemate construction lay in the design of the 'great tumuli' at Kerma in Sudan. This adaptation of a foreign construction technique is reminiscent of the appearance of niched brick construction during the Archaic Period in Egypt.

At Kerma, located along the Dongola Reach of Upper Nubia, a pattern of internal buttressing walls developed in the great funerary tumuli constructed at the end of the Classic phase of the civilization coeval with the late Second Intermediate Period in Egypt. The North Palace at Deir el-Ballas in Upper Egypt, which is contemporary with these last tumuli at Kerma. is the earliest example of a true casemate foundation in Egypt. The casemates employed there, very long narrow chambers filled in with earth and gravel and capped with a pavement of mud brick one course thick, is exactly the same as in the tumuli. Indeed, the very design of the casemate walls is the same, usually two and one half bricks thick, spaced out between 205-250 centimeters wide, and paved over with a single layer of brick. This pattern is not followed by any of the Near Eastern or purported Egyptian parallels that have previously been suggested as antecedents for this construction technique.

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[1] Josephson (2005); Spencer (1979) pp. 120-122.
[2] Lacovara (2006).
[3] Lacovara (2006) pp. 192-193.
[4] Małecka-Drozd (2012); Małecka-Drozd (2014)
[5] Bietak (2010) p. 21.
[6] Kempinski (1992) Fig. 13.
[7] Małecka-Drozd (2014) p. 159.

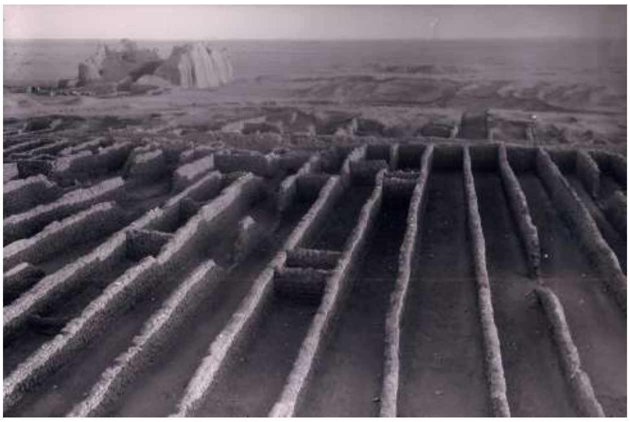

Figure 1: The Tumulus K III at Kerma looking towards the funerary Chapel K II.
© Photograph courtesy Museum of Fine Arts Boston

1. THE NUBIAN CONNECTION

The Kerma tumuli[8] evidence a construction technique involving a pattern of rectilinear internal buttressing walls which developed at the end of the Classic phase of the civilization coeval with the late Second Intermediate Period in Egypt (Fig. 1) (ca. 1650-1550o B.C.).[9] The evolution of this building technique can be traced from tumulus K XVI, which had no internal cross walls, through the tumuli K X, K IV and, finally, K III. In order to stabilize the great mounds,[10] a network of crossed walls was constructed in advance, and then the chambers filled with earth and stone rubble and then were roofed over with a pavement of mud brick (Fig. 2).

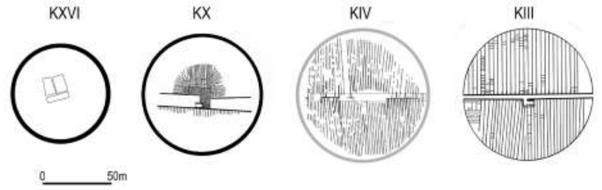

Figure 2: The development of the Great Tumuli at Kerma.
© Drawing by A. Boyce after Reisner (1923)

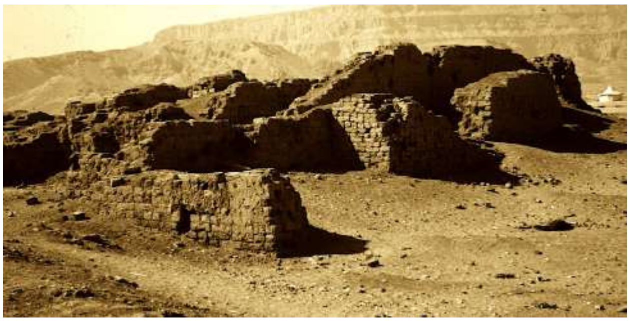

Figure 3: The North Palace casemates uncovered in the 1900-01 excavations.
© Photograph courtesy Museum of Fine Arts Boston

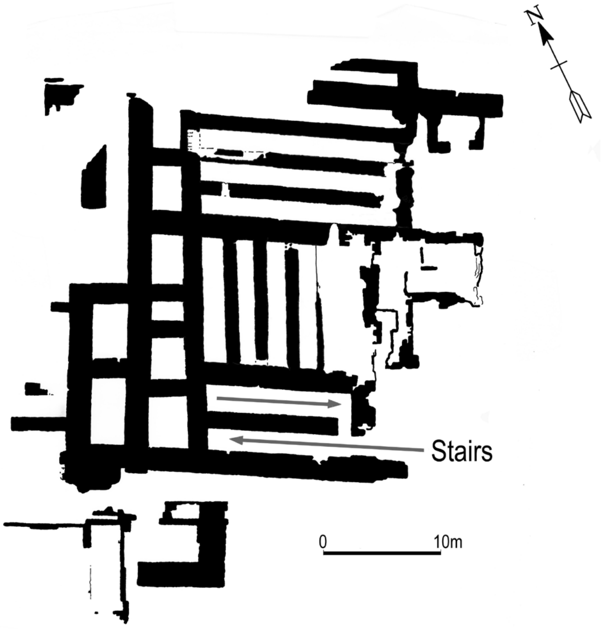

Figure 4: The casemate core of the North Palace at Deir el-Ballas.
© Drawing by A. Boyce

The North Palace at Deir el-Ballas[11] (Figs. 3 and 4) is contemporary with these last tumuli and the pattern of the casemates used there to form an elevated second story in the core of the structure, is exactly the same in size and pattern as in Tumuli K III at Kerma (Fig. 5).[12] The configuration of the casemates in the North Palace is nowhere followed as closely by any of the Near Eastern or purported Egyptian parallels cited by Malecka-Drozd.[13]

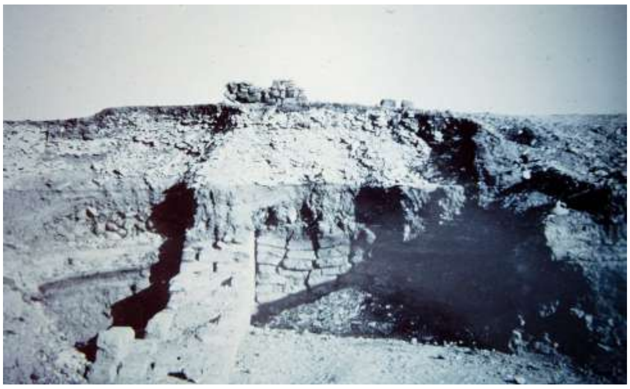

Figure 5: Casemate fill revealed in the 1900-01 excavations.
© Photograph courtesy Museum of Fine Arts Boston

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[8] Bonnet (2012).

[9] On the chronology of the tumuli see: Lacovara (1987).

[10] Reisner (1923) pp. 82-98.

[11] Lacovara (1990) pp. 2-3.

[12] Reisner (1923) p. 135.

[13] Małecka-Drozd (2012) p. 76.

Moreover, the large amount of imported Kerma ceramic material found at Deir el-Ballas[14] and textual references to Nubians at the site[15] demonstrates the cultural interaction that must have taken place there.[16] This is also evident architecturally, not only in the use of similar rectangular faience wall tiles for decoration,[17] but also in the designs of the palatial structures at both sites. The building at Kerma identified as a royal palace by Charles Bonnet[18] was modified with the addition of a long off-axis entrance corridor (Fig. 6) of exactly the same design as that found in the North Palace at Deir el-Ballas (Fig. 7).[19]

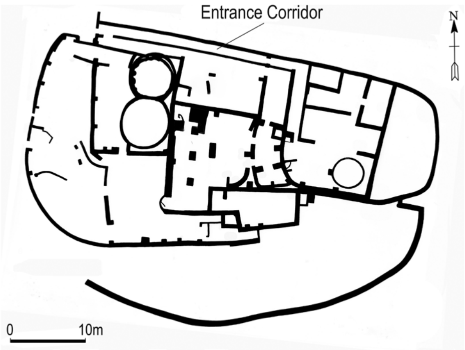

Figure 6: The Royal Palace at Kerma with the later addition of a long, off-axis entrance corridor.
© Drawing by A. Boyce after drawing by Kerma mission

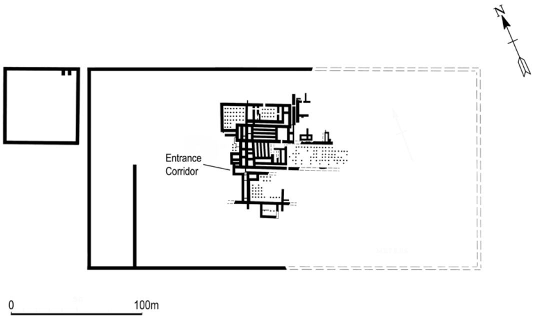

Figure 7: The North Palace at Deir el-Ballas with its long, off-axis entrance corridor.
© Drawing by A. Boyce

While the technique at Kerma is used for tumuli and not for buildings, such as the deffufas,[20] that does not preclude its use in Egypt for other purposes. Just as in the case of the adoption of niched brick architecture, which had developed for temples in Mesopotamia but was then used for palaces and tombs in Egypt, it is an adaptation of a technique and not a wholesale copy of a form.

2. CASEMATES AT DEIR EL-BALLAS

While having different functions, the buttress walls at Kerma to stabilize the tumuli, as opposed to the casemate foundations at Deir el-Ballas, which served to support an elevated story in the North Palace, the inspiration seems to have been clear. The Egyptian genius lay not so much in invention as in adaptation and refinement. We can see this re-envisioning in the platform structure known as the "South Palace" at Deir el-Ballas.[21] Although it was termed the "South Palace" by George Andrew Reisner, its original excavator, the structure was in fact not a royal residence, but instead appears to have served as a watchtower constructed to enable an unencumbered view of the Nile and surrounding countryside. It would have served to allow soldiers to observe ships and troops as they assembled for the campaign against the Hyksos. The lack of any domestic features and the paucity of sherd material in and around the structure indicates its non-residential function.

The bricks used in its construction were slightly smaller (ca. 47cm. x 23 cm. x 11 cm.) than those used in the North Palace (ca. 54 cm. x 26 cm. x18 cm.) and reed matting was employed between some courses. This same building technique was also used in an extension to the main enclosure wall of the North Palace, indicating a date slightly after the construction of the royal palace. At the "South Palace" the ancient builders used casemates to incorporate a natural hill to make a large terrace and platform approximately 100 meters long by 44 meters wide. Casemates were also adapted to form a level foundation on the downward slope of the hill to form a terrace and to encase the hilltop to regularize it and give it the appearance of a building. There are no interior rooms in the structure, just a broad staircase that leads to the top of the platform (Fig. 8). This pattern of campaign palace and watchtower may have already had an earlier precedent in the Middle Kingdom palace and an associated watch post on a hill reached by a stairway at Uronarti.[22]

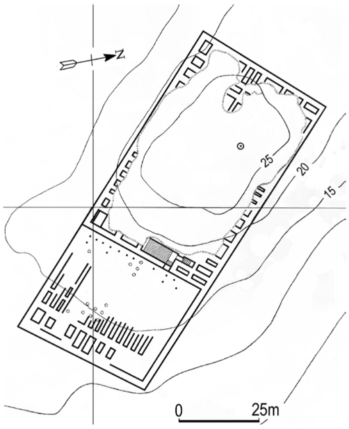

Figure 8: The "South Palace" at Deir el-Ballas.
© Drawing by A. Boyce

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[14] Bourriau (1990).

[15] Quirke and Allon (forthcoming).

[16] We are now beginning to realize the complex interplay between Nubian and Egyptian cultures, cf. van Pelt (2013); Smith (2013).

[17] Elizabeth Minor (2012) p. 112.

[18] Bonnet and Valbelle (2014) pp. 165-167.

[19] Lacovara (1997). 41, Fig. 37; While long entrance corridors are already found in the Kahun mansions , cf. Badawy (1966) 24, the pattern seen here of the corridor combined with the square gatehouse, is not.

[20] Cf. Bonnet (2000).

[21] Lacovara (1990) p. 5.

[22] Knoblauch and Bestock (2013) pp. 130-136;. I would like to thank Christian Knoblauch for this reference.

3. CASEMATES IN THE DELTA

As Deir el-Ballas had been founded as a campaign palace for the Theban princes in their war against the Hyksos, once the conquest of Avaris was completed, the North Palace was abandoned. Remarkably, over the ruins of the Hyksos capital, Ahmose seems to have erected replicas of the North Palace and "South Palace." Palace G and F at Ezbet Helmi[23] mirror the style, size, and relationship of the North Palace and "South Palace" at Deir el-Ballas (Fig. 9). Palace F measured 70.5 x 47 meters, similar in size to the "South Palace" at Deir el-Ballas and was also composed of a casemate foundation above which no superstructure was preserved. The top of the platform was reached by a ramp 6.40 meters in width attached to the north-eastern edge of the platform. It is located at the Northwestern edge of the palace compound overlooking the Pelusiac Branch of the Nile evoking the position of the 'South Palace' at Deir el-Ballas intended to observe river traffic. The plan is also similar consisting of squared casemates surrounding a central core. The remains of a possibly slightly earlier structure in Area H/III stratum D/2 is again similar in design (Fig. 10),[24] however the date is questionable and could be within the early 18th Dynasty.[25] Both these buildings at Ezbet Helmi replicate the outward design created for the "South Palace" but without the core of the natural hill, indicating that the design originally created for that specific locale was later adapted to create these solid structures.

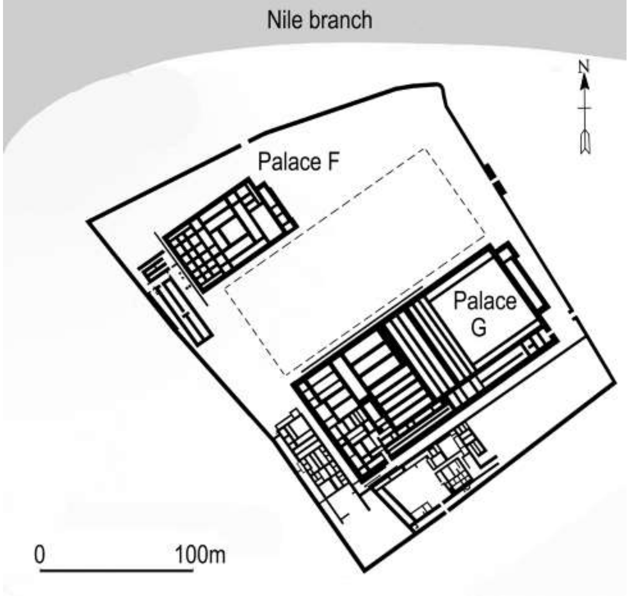

Figure 9: Palaces F and G at Ezbet Helmi.
© Drawing by A. Boyce

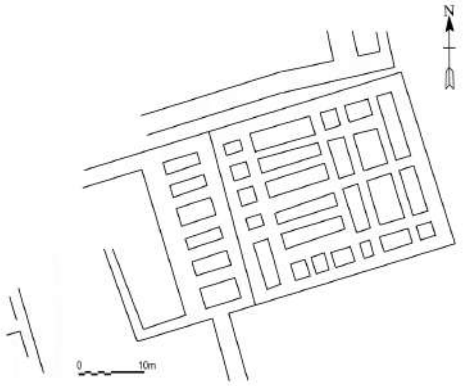

Figure 10: Platform at Area H III stratum D2 at Ezbet Helmi.
© Drawing by A. Boyce

On the other hand, Palace G is larger, measuring 168 x 78.75 meters and is composed of long, narrow casemates set perpendicular and fronting a large square open court, just like the North Palace at Deir el-Ballas. While the exact extent of the core plan of the North Palace is unclear, the traces suggest an approximately similar size. Other than in replicating the pattern found at Deir el-Ballas, there would seem to be no reason why the construction methods used in these two 'palaces' in the Delta would be so different. This correspondence also underscores the earlier date proposed for the Ezbet Helmi structures.[26] It should also be noted that the pattern of long, narrow casemates derived from the Kerma tumuli and used in the North Palace at Deir el-Ballas and Palace G is no longer used and a more regularized pattern of squared casemates developed at the "South Palace" becomes the standard for all later casemate platforms.

4. ALTERNATIVE ORIGINS

While the evidence for the Nubian origin of the casemate technique is compelling, the Egyptian or Near Eastern possibilities that have been suggested are problematic. One source posited are the brick tombs of the Archaic Period[27] at Giza, Saqqara, and Naqada, which are constructed around a series of open magazines, however many of these chambers functioned as magazines for funerary offerings with only some filled in with earth, sand or gravel. In addition, this type of tomb design does not survive into the Old Kingdom or later,[28] and the mounded foundations of early temples also does not present a convincing precedent for the specific architectural form of lalter casemate foundations.

Another suggestion for an indigenous antecedent for casemate foundations is the construction of a defensive wall at Aswan that had within it rubble filled boxes, presumably to speed and strengthen the construction.[29] Here again, this appears to have been a temporally restricted use of this technique. Another possible forerunner put forward are the platform bases of a number of earlier temples such as that of Mentuhotep II in Deir el-Bahari,[30] or the White Chapel of Senusret I at Karnak.[31] But none of these are constructed on the type of casemate foundations that are being discussed here. The suggestion that "the first example of a building which can be considered to have been erected on a casemate platform is a palace from area F/II of Avaris made up of several sectors arranged around a central tower,"[32] is not a clear predecessor in that it is composed of a series of open storerooms, not casemate chambers. While, casemate construction is found in a number of different contexts in the Near East from the Neolithic to the Iron Age,[33] in materials, design, and function it does not appear to have influenced Egyptian architecture.

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[23] Bietak (1996) pp. 67-73.

[24] Janosi (1996); Fuscaldo (2000) pp. 19-20.

[25] Janosi (1996) p. 96.

[26] Cline (1998).

[27] Cf. Emery (1954) pl. 38.

[28] Małecka-Drozd (2014) pp. 160-162

CONCLUSIONS

This discussion is reminiscent of the insular stance taken by some scholars in the debate surrounding the appearance of niched brick construction during the Archaic Period in Egypt. While Henri Frankfort clearly demonstrated the prior evolution of the technique of niched brick architecture in the Near East before its appearance in the Nile Valley,[34] it was still disputed by some Egyptologists who sought to find local precedents for the style.[35] This reticence, in part, may be due to the tendency of some scholars to over-identify with their subject[36] and refuse to acknowledge foreign influences as important to the development of pharaonic culture. This reluctance is perhaps even more vehement when that inspiration comes from Nubia, given the inherent bias evident regarding the African nature of ancient Egypt.[37] In both the case of niched-brick architecture and casemate construction, we see an architectural form evolving outside of Egypt and then appearing fully developed in the two lands without a clear, autochthonous forerunner.

Lastly Małecka-Drozd's suggestion that these casemate foundations appeared as a protection against flooding[38] is obviously disproven by the situation of the "South Palace" atop a tall hill and being used only for the elevated portion of the North Palace also built out in the desert, as well as later structures such as the Kom el ʼAbd,[39] and Amun temple at Malqata.[40] While casemates may have helped prevent flooding, at least temporarily in some cases, it was clearly neither their sole purpose or the motive for their development.

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[29] Jaritz (1993).

[30] Arnold (1979) pp. 16-17.

[31] Chevrier and Lacau (1956).

[32] Małecka-Drozd (2014) p. 150.

[33] Kempinski and Reich (1994) pp. 279-280.

[34] Frankfort (1941).

[35] Cf. Kelley (1974) and Hendrickx, who tries to find something that might suggest and independent invention but has to eventually admit that, in fact, it "…could be the result of indirect Mesopotamian influence…" Hendrickx (2001) p. 104.

[36] Cooney (2021) 32-37.

[37] Cf. Lemos (2023); Matić (2018).

[38] Małecka-Drozd (2012) pp. 89-90.

[39] Kemp (1977).

[40] Koltsida (2007).

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NILE MUD-BRICK ARCHITECTURE AS SEEN IN THE CALOTYPES OF FÉLIX TEYNARD

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SUMMARY

To add to our knowledge of the monuments erected since Antiquity on the banks of the Nile, Félix Teynard organized an expedition -from Cairo up to the Second Cataract- during the winter of 1851-1852. Adjusting his shots to the plates of the great "*Description de l'Egypte*" and those published by François Chrétien Gau in "*Antiquités de la Nubie*", he has used an emerging photographic technique: that of the calotypes. In 1858, he has published them in an *Album*, organized in two parts: one for Egyptian sites and the other for Nubian ones. Fifty-seven plates of this *Album* are preserved at the Egyptological research centre of the sorbonne (CRES).

The perfection of the pictures, edited in an *elephant folio* size is exceptional. The scientific method followed by F. Teynard can be added to this. Each picture is referenced by a number, transferred on maps or plans drawn by himself, and including the precise indication of the viewing angle. A metric scale, a wind rose and the course of the Nile complete the data. He also added for each plate a descriptive note, as informative as possible.

These calotypes may allow to reveal elements of ancient mud architecture, nowadays modified, moved or even disappeared, coming from antiquity until the mid-XIXth century.

INTRODUCTION

This autumn, while I was preparing this conference for *Nile's Earth*, I have noticed in the local magazine *Habitat*[1] the interest of regional press for the use of mud-bricks in buildings. I asked to the French *Centre Scientifique et Technique du Bâtiment* [2]: and it was confirmed to me that the certification of mud-bricks is now underway. As mud-bricks buildings can be seen on calotypes, the question for me was: how XIXth century photographic views can contribute to the study of mud-brick (uses, modifications or alterations), and especially Felix Teynard's ones?

F. Teynard lived and worked in the beautiful mountains surrounding Grenoble. *Nile's Earth* international conference, held in his city, was a perfect opportunity for me to thank him for the multidisciplinary gift he has done to our knowledge of ancient Egypt and Nubia.

1. F. TEYNARD AND HIS WORK

1.1 A GRENOBLE-BASED ENGINEER

Félix Teynard was a discreet engineer whose career took place in Grenoble (Isère) and its surroundings[3]. He was born in 1817 in Saint-Flour (Cantal) and died in 1892 at Saint-Martin-le-

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[1] *Habitat* (Fall 2022-67), p. 5.

[2] CSTB is a French national public establishment of industrial and commercial nature http://www.cstb.fr/fr/.

[3] Cf. Aubenas S., « Félix Teynard (1817-1892) » http://expositions.bnf.fr/veo/photographes/ssindex02.htm.

Vinoux (Isère)[4]. He was married in 1856 in Grenoble[5], has two children, and is buried in Grenoble.

1.2 THE GREAT "DESCRIPTION DE L' EGYPTE"

He has achieved a real scientific feat by completing plates of the great "*Description de l'Egypte*"[6] and those of François Chrétien Gau, "*Antiquités de la Nubie*"[7], by using an emerging photographic technique: that of calotypes (or talbotype) process. Calotype technic is an early photographic process, developed in England by William Henry Fox Talbot by the 1830s[8]. W. Talbot's photographic technique has been tested by the famous Maxime Du Camp in Egypt, a few months before F. Teynard's photographic expedition on the Nile.

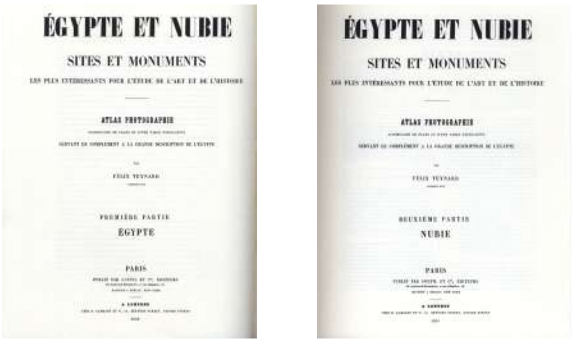
1.3 FULFILMENT OF THE MISSION

F. Teynard organized the expedition himself, which took place during the winter of 1851-1852. He has sailed up the Nile until the Second Cataract and published in 1858 a luxurious album in A-2-elephant folio format (40 cm high x 52 cm wide), generally referred to as "Teynard's Photographic Atlas"[9]. This *Album photographié* was published in two parts: eighty-three plates for Egyptian sites and seventy-seven plates for Nubian sites[10] (Fig. 1a-b). The Historian of photography Kathleen Stewart Howe, with the help of the Egyptologist Catharine H. Roehrig published in 1992 a systematic survey of F. Teynard's *Album*[11], and then Sylvie Aubenas, Historian of XIXth century photography, specialist in orientalist photographers has completed the study of F. Teynard's work.

2. AN ENGINEER AND HIS APPROACH

2.1 THE METHOD

The method developed by F. Teynard, which is clear and precise, is dazzling. He has published a hundred and sixty plates in A2 format, wrote a well-done historical introduction, created a documented notice for each calotype and took a real interest in ancient and modern Egyptian civilisation, history, geography and natural environment surrounding Egypt and Nubia. But above all, each plate is referenced (Egypt or Nubia / site / monuments(s) / alphabetic point). He also drew a map of the Nile with the sites, and maps of the two most important places he documented, namely the temples of Karnak and the monuments on the island of Philae.



ÉGYPTE ET NUBIE
SITES ET MONUMENTS
ATLAS PHOTOGRAPHIÉ
FÉLIX TEYNARD
PREMIÈRE PARTIE
ÉGYPTE
PARIS

ÉGYPTE ET NUBIE
SITES ET MONUMENTS
ATLAS PHOTOGRAPHIÉ
FÉLIX TEYNARD
DEUXIÈME PARTIE
NUBIE
PARIS

Figure 1a-b: Title pages of the two volumes of the Album, with all the necessary details to understand their content.
© Stewart Howe 1992, p. 108 and 123

2.2 ON PHILAE ISLAND, DURING WINTER 1851-1852

On the map of the Island of Philae, for example (Fig. 2a)[12], he indicated the course of the Nile, drew a wind rose and a metric-scale. To complete the data, each plate of the *Album* is referenced on the map by a letter, showing the viewing angle of the shots. In the Nubian part of the Album, F. Teynard published nineteen views of Philae, general views of the site, general views of the island itself and views of the sanctuaries (*Album*, plates 86 to 103). The numerous mud-brick remains surrounding the island of Philae are particularly highlighted. On plate 89 (Fig. 2b)[13], the southern side of the kiosk of Emperor Trajan is shown viewed from Point "D" as indicated on the map of Philae. If F. Teynard drew a wind rose as in the *Description de l'Egypte* and used alphabetic points as in F. Ch. Gau's book, he also chose to add the viewing angle of each point (*cf* Fig. 2a). Today, all these indications can be valuable sources of data, each site being modified since (Fig. 2c).

3. THE ALBUM

3.1 THE FRENCH LEGAL DEPOSIT OF THE *ALBUM*

We still do not know how F. Teynard gathered all the financial and administrative supports necessary for such an expedition to Egypt and Nubia. We just understand that he had initiated close relations with the French Academy of Sciences. Few complete copies of his *Album photographié* are known all around the world (about eleven), a magnificent publica-

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[4] Death record : Saint-Martin-d'Hères, Archives départementales de l'Isère et du Dauphiné, Cote 9NUM/5E424/9 (Thanks to Karine Madrigal).

[5] Wedding record : Saint-Martin-d'Hères, Archives départementales de l'Isère et du Dauphiné, Cote : 9NUM/5E186/24/215 (Thanks to Karine Madrigal).

[6] *[…]ou Recueil des observations et des recherches qui ont été faites en Égypte pendant l'expédition de l'Armée française* (View online: gallica.bnf.fr / Bibliothèque nationale de France).

[7] Gau F. Ch., *Antiquités de la Nubie ou monumens inédits des bords du Nil, situés entre le première et la seconde cataracte, dessinés et mesurés, en 1819*, Stuttgart, J. C. Gotta, Paris, Firmin Didot, 1822 (View online: https://digitalcollections.nypl.org/collections/antiquits-de-la-nubie-ou-monumens-indits-des-bords-du-nil-situs-entre-la-premire#/?tab=about&scroll=6 (New York Public Library).

[8] « Calotype », in *Encyclopædia Britannica Online*, https://www.britannica.com/technology/calotype and AUBENAS S., ROUBERT P.-L. (dir.), *Primitifs de la photographie : le calotype en France, 1843-1860*, Paris, BnF/Gallimard, 2010.

[9] Teynard F., *Égypte et Nubie : sites et monuments les plus intéressants pour l'étude de l'art et de l'histoire. Atlas photographié accompagné de plans et d'une table explicative servant de complément à la grande Description de l'Égypte. Première partie : Egypte, deuxième partie : Nubie,* Paris, Goupil et Cie ; London, E. Gambart and Co., 1858.

[10] View online: gallica.bnf.fr / Bibliothèque nationale de France.

[11] Howe K. S., *Félix Teynard: Calotypes of Egypt. A catalogue raisonné*, New York, Hans P. Kraus JR.; London, Robert Hershkowitz; Carmel, Weston Gallery, 1992.

[12] F. Teynard's *Album*, pl. 85 bis.

[13] CRES, Inv. Ph. Teynard N° 089, coming from Dépôt légal Seine (1853) N° 7889.

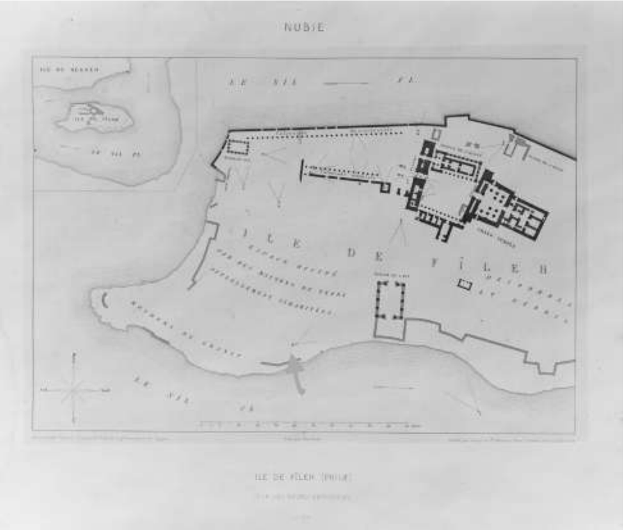

Figure 2a: Teynard (pl. 85b): map of Philae.
© Washington, Library of Congress Prints and Photographs

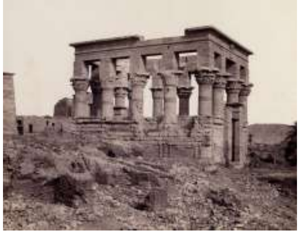

Figure 2b: Teynard (pl. 89): Trajan's kiosk on Philae Island, from the Southern side.
© N. Lienhard (CRES)

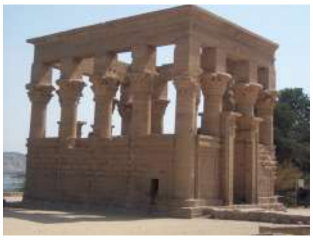

Figure 2c: Touristic view of Trajan's kiosk from Northern side, now in Agilkia Island.
© N. Lienhard (CRES)

tion gradually achieved between 1853 and 1854 in thirty-two issues of five plates each. The Egyptological Research Centre of the Sorbonne (CRES) keeps fifty-seven calotypes, coming from the legal registration of this precious *Album*. All are registered with red ink "Dépôt légal Seine (1953)", with an inventory number, hand-written in black ink or graphite (*Cf* Fig. 2b for example).

3.2 TEYNARD'S CALOTYPES: A MISSING LINK?

In addition to the fine method followed by F. Teynard, why should these prints be so documentary? Because of extreme climatic conditions in Egypt and Nubia, even in winter, F. Teynard had to adjust every day the necessary chemicals used for a successful negative. And then, thanks to the calotype process, the picture was revealed on the screen of a paper, and the treatment of the surface with a salt solution further improved the quality of the print. The result is perfect images, in a very good state of preservation, published in an elephant-folio format. All these monuments, landscapes or villages are today different, or have even disappeared. F. Teynard's *Album* is the reflection of a trip, made a few months before Auguste Mariette's general excavations campaigns in Egypt. It can also offer a scientific vision of the ancient banks of the Nile. Because of the exceptional quality of the photographs, the epigraphers can find in them inscriptions and graffiti of any period, today erased or disappeared. If F. Teynard's calotypes are a truly missing link for archaeologists, they can also be useful for studying ancient Nile mud-brick constructions.

4. ARABIAN TOWNS AND CITIES

4.1 ARABIAN MONUMENTS AND DWELLINGS

This *Album* comprises not only antique but also modern architecture, with mosques, Arabian villages, towns and cemeteries. In fact, F. Teynard's *Album* begins at Cairo with, from the very first plates, pictures of mud-brick mosques. The Egyptological library of the Sorbonne only keeps plates with pharaonic monuments, but the complete *Album* can be seen in online catalogues. One example, coming from the online catalogue of the French National Library: that of the Nubian ancient town of Ed-Deir, now submerged under Lake Nasser. Looking on pl. 137 of the *Album (*with its priceless negatives[14]), the picture of a beautiful mud-brick house, built at a crossroad, can be observed (Fig. 3 a-d). The high resolution of F. Teynard's calotypes can be seen, enabling us to examine the technique for laying mud-bricks.

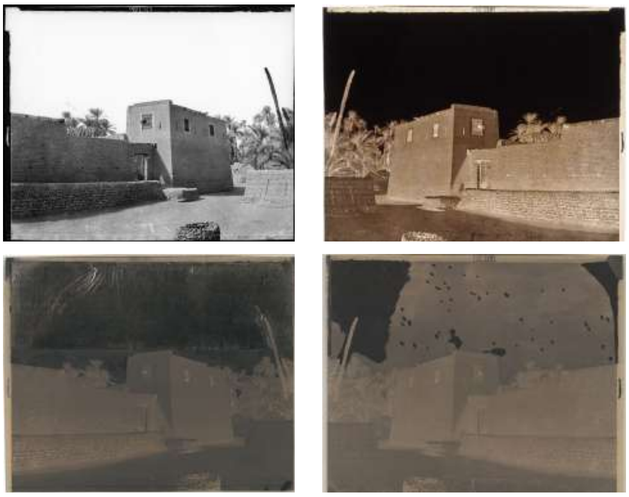

Figure 3a-d: Teynard (pl. 137): Crossroad and private house at Ed-Deir.
© BNF negative photography Album, Gallica.BNF.fr

4.2 MODERN GARDENS

F. Teynard did not fail to take pictures of some gardens, all protected by mud-brick walls. In the temple complex of Karnak, the enclosure built to protect palm tree plantations can be seen on pl. 44 of the *Album* (point B of F. Teynard's map)[15] or on pl. 67 (view taken from point G)[16] (Fig. 4a-c).

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[14] BNF negative photography Album, pl. 137. Online French National Library web site: http://catalogue.bnf.fr/ark:/12148/cb43644860s

[15] CRES, Inv. Ph. Teynard N° 044, coming from Dépôt légal Seine (1853) N° 5667.

[16] CRES, Inv. Ph. Teynard N° 067, coming from Dépôt légal Seine (1853) N° 6157.

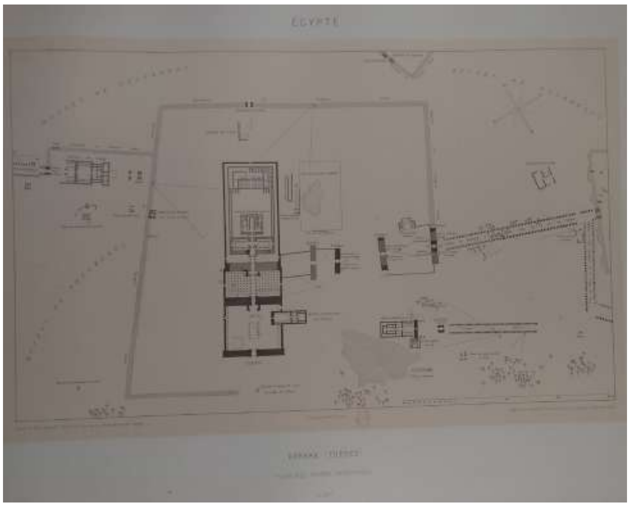

Figure 4a: F. Teynard (pl. 42bis): general map of Karnak.
© R. Mathis (Bibliothèque Nationale de France)

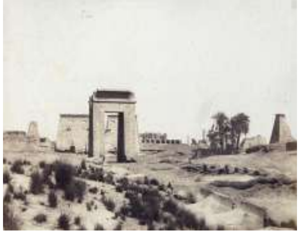

Figure 4b: F. Teynard (pl. 44): Karnak temple, Khonsu Dromos, Sphinxes Avenue in front of Evergete's gate.
© N. Lienhard (CRES)

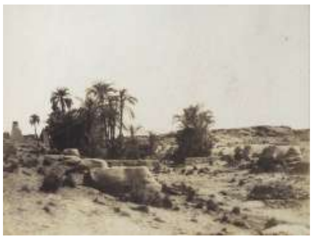

Figure 4c: F. Teynard (pl. 67): Karnak temple, Mut Dromos, Avenue of criosphinxes.
© N. Lienhard (CRES)

5. PHARAONICS MONUMENTS INCLUDING MUD-BRICK BUILDINGS

5.1 AN ALMOST UNDISTURBED ARCHAEOLOGICAL CONTEXT

The majority of the *Album* shows pharaonic monuments. Alarmed by the degradation of monuments, F. Teynard tried to preserve some visual evidence by taking photographs of them. His *Album* was intended to serve as a supplement to the great *Description de l'Egypte*, as it is written in its title. He was lucky, because in the 1850's, it was possible to photograph remains of ancient or modern buildings in a still preserved archaeological context.

The best examples are pharaonic temples, built in stone and easily accessibles; they were perfect places for "new" buildings. As can be seen on F. Teynard's calotypes, Greco-Roman sanctuaries were gradually covered by millennia of debris of all kinds and all times (pharaonic to mid-XIXth century). But it's worth pointing out that, fortunately, those new buildings, all made of mud-bricks, had protected many pharaonic ones from destruction.

5.2 LARGE MONUMENTS IN STONE, USED AS FOUNDATION FOR MUD-BRICK BUILDINGS

Large and solid monuments, pharaonic temples were used as foundation for mud-brick buildings**.** They had been converted -according to the times- into churches or mosques, barracks buildings, farm facilities or even individual dwellings. F. Teynard's *Album* is a real picture book of secondary mud-buildings, from various periods and all along the Nile. A quick look to a selection of plates kept at the CRES are evidence for this.

In Qena district (Middle-Egypt), remains of houses and of a *sanatorium* -but in fact a *tinctorium*- can be seen around the temple of Hathor in Dendara (pl. 23[17], Fig. 5a**).** And, inside the temple**,** the famous Hathoric kiosk built on the terrace is converted into a dwelling (pl. 26[18], Fig. 5b**)**.

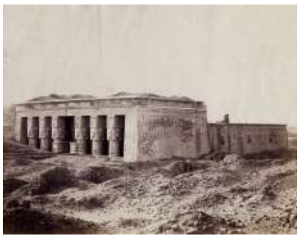

Figure 5a: F. Teynard (calotype pl. 23): Dendara, general view of the Hathor Temple.
© N. Lienhard (CRES)

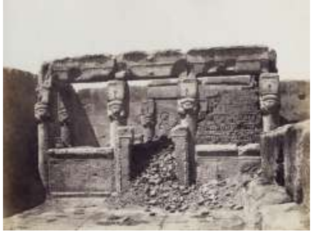

Figure 5b: F. Teynard (calotype pl. 26): Dendara, Hathoric kiosq as a mud-brick dwelling.
© N. Lienhard (CRES)

Among the works which are still to be completed for the study of the *Album*, one is to be able to identify some ancient mud-brick monuments (religious, military or private buildings or dwellings, secondary buildings and so on). For example, in Upper-Egypt, a modern podium/platform can be seen at the rear part of the temple of Luxor (*Album* pl. 32[19], Fig. 6a). But this platform is not yet understood. As another example, on the other side of the Nile, abandoned mud-brick houses of later periods can be seen in the Medinet-Habu temples. On F. Teynard's plate 34, they are built along, and perhaps in, the mud-brick *temenos* of this temple, just around the two East gate guardhouse lodges (*Album* pl. 34[20], Fig. 6b).

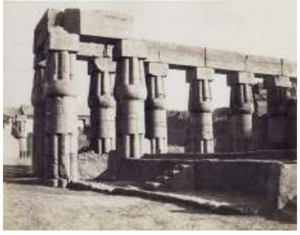

Figure 6a: F. Teynard (calotype pl. 32): Luxor Temple, mud-bricks plateforms with staircases.
© N. Lienhard (CRES)

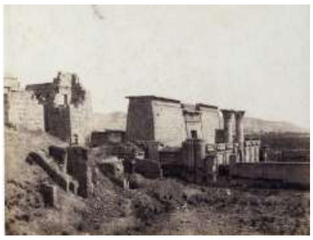

Figure 6b: F. Teynard (calotype pl. 34): Medinet Habu, East gate leading to Migdol, looking to S-E.
© N. Lienhard (CRES)

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[17] CRES, Inv. Ph. Teynard N° 023, coming from Dépôt légal Seine (1853) N° 3027.

[18] CRES, Inv. Ph. Teynard N° 026, coming from Dépôt légal Seine (1853) N° 5679.

[19] CRES, Inv. Ph. Teynard N° 032, coming from *Dépôt légal Seine (1853)* N° 3033 or 3055.

[20] CRES, Inv. Ph. Teynard N° 034, coming from *Dépôt légal Seine (1853)* N° ° 5659.

A little further along the Nile, at Armant, one plate of the *Album* shows the mammisi build by Cleopatre VII Philopator for the birth of her son, Ptolemee XVI Cesarion (*Album* pl. 69[21], Fig. 7a).This plate is a wonderful example of the use of modern mud-brick monuments in Egyptian temples. In fact, according to the unique overview he published, some parts of the mammisi were re-used as a farm, built in mud-bricks. Even a nice dovecote can be seen on the right, protected by Nile-mud walls. The sanctuary was described and pictured in the great "*Description de l'Egypte*" [22] as a *Typhonium,* but without the modern mud-brick farm and with an Islamic mausoleum in place of the dovecote (*Description de l'Egypte* pl. 91, Fig. 7b[23]). Then, the sanctuary was identified by Jean-François Champollion as Cleopatra's mammisi in november 1828. Visiting the site in 1851, Maxime Du Camp looked at those those mud-build dwellings and described them as "a stable".

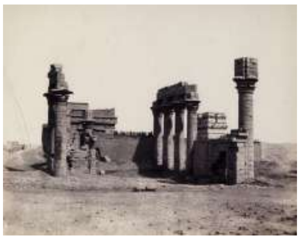

Figure 7a: F. Teynard (calotype pl. 69): Montu-Ra temple at Armant, a general view of the ruins.
© N. Lienhard (CRES)

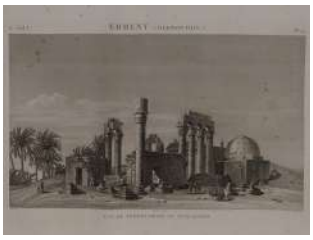

Figure 7b: Temple view, from South-West.
© *Description de l'Egypte, Antiquités*, vol. I, Erment (Hermonthis) pl. 91. Gallica.Bnf.fr/ Bibliothèque municipale de Toulouse

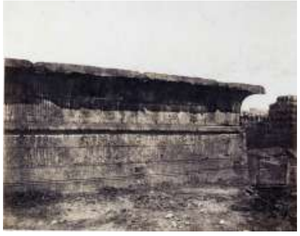

Figure 8a: F. Teynard (calotype pl. 70): looking at the roof-corniche of the pronaos (N-E side).
© N. Lienhard (CRES)

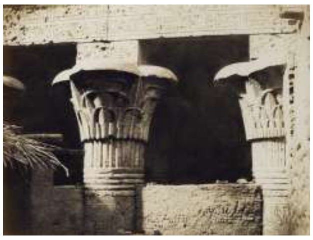

Figure 8b: F. Teynard (calotype pl. 71): entrance to the pronaos.
© N. Lienhard (CRES)

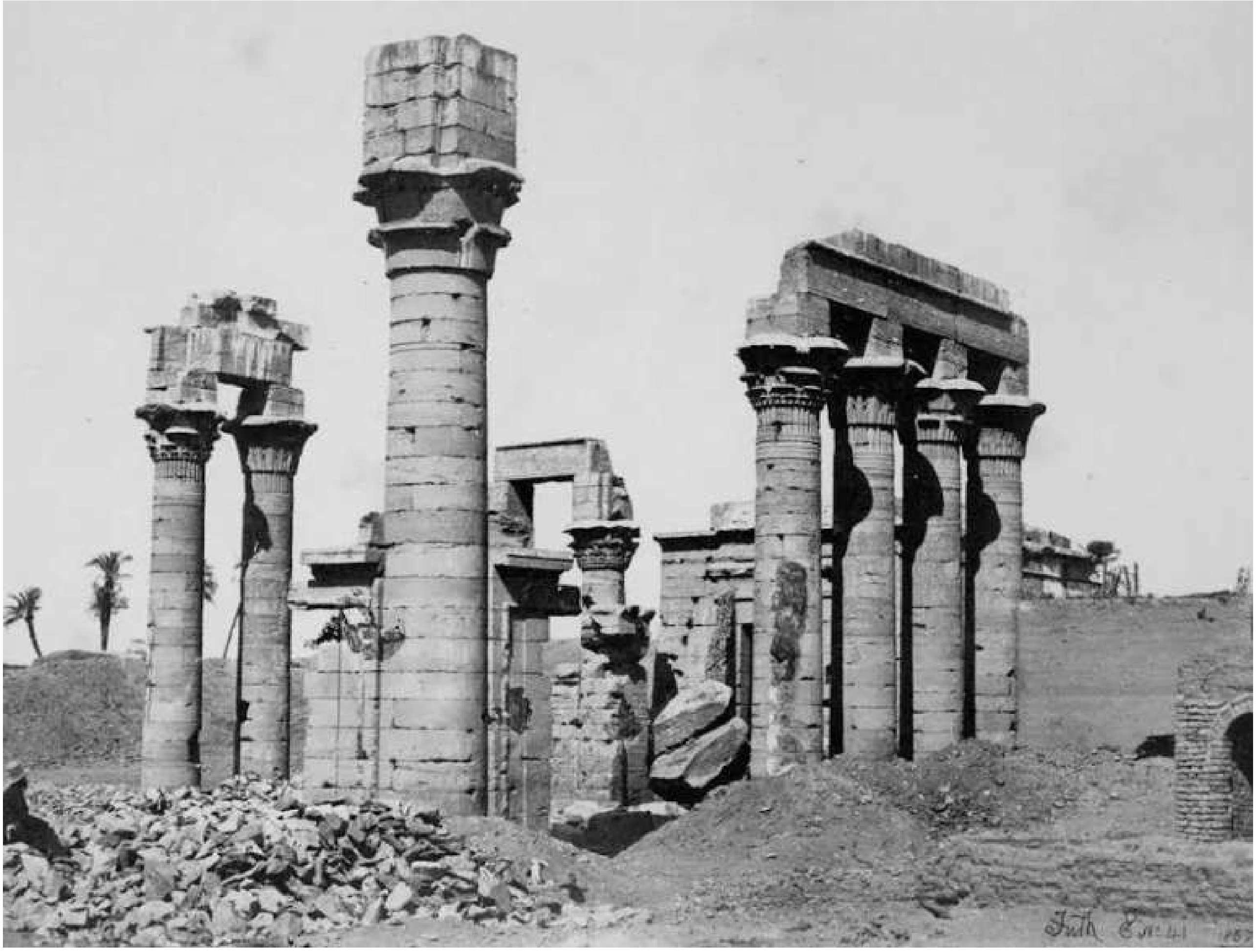

Figure 7c: One of the two views of the mammisi pictured by F. Frith in 1857: *Cleopatra's temple at Erment*, near Thebes.
© Bibliothèque de l'Institut National d'Histoire de l'Art, collections Jacques Doucet, Frith E N° 41.

[21] CRES, Inv. Ph. Teynard N° 069, coming from *Dépôt légal Seine (1853)* N° 6941.

[22] *"Description de l'Egypte" (Antiquités, textes, chap. VIII pp. 409-437 and planches*, vol. I, Erment (Hermonthis) pl. 97 à 99.

[23] Source Gallica.Bnf.fr/Bibliothèque municipale de Toulouse

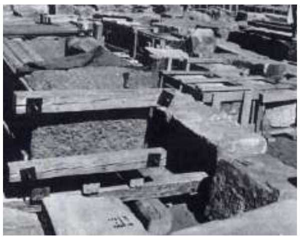

Figure 9a: Debod and Taffeh temple blocks just dismantled in the 1960's and stored on Elephantine Island.
© J. K. van der Haagen (UNESCO)

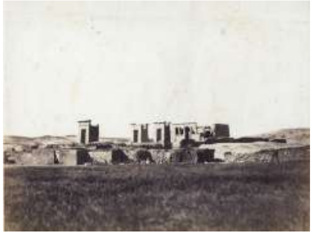

Figure 9b: F. Teynard (calotype pl. 106): general view of disappeared land.
© N. Lienhard (CRES)

Then, F. Teynard pictured them during winter 1851-1852 (Fig. 7a). In 1857, a little after Teynard's expedition, Francis Frith took two views of the mammisi, showing that the dismantling of the mud-brick buildings was in progress (Fig. 7c[24]). In fact, about ten years after F. Teynard's travel in 1851-1852, the walls of Cleopatre's mammisi were removed to build a sugar refining factory in 1861-1862. By the second part of the XIX^th^ Century, the ancient egyptian sanctuary and the modern mud-brick buildings had disappeared. As far as I khnow, Teynard's plate 69 seems to be the unique complete view of those mud-brick buildings.

One more site to mention is Esna, where the rear part of the temple dedicated to Khnum was partially buried under modern buildings (cf. Fig. 8a). Wanting to take pictures of the roof-corniche (*Album* pl. 70[25], Fig. 8a), F. Teynard climbed up to the terrace of a private mud brick house, built in the temple. The staircase that he used can be seen on the right of the picture. In this temple, the access to the pronaos was restricted by a modern mud-brick wall (*Album* pl. 71[26], Fig. 8b). F. Teynard, who wrote commentary for all the pictures, suggested that this wall was built to prevent anybody or anything falling into the temple, which had become the foundation of part of a modern village.

This survey about ancient mud-brick buildings in the archives of CRES can be concluded in Nubia, with the Amun temple in Dabod. F. Teynard published two views of this temple (Album pl. 106 - 107), now rescued from the waters of Lake Nasser (Fig. 9a)[27] and rebuilt since 1972 in Madrid. On the general view of the temple, images of mud dwellings, mostly disused, are preserved (*Album* pl. 106[28], Fig. 9b). Like most of the Nubian temples rescued under the aegis of UNESCO, the temple of Dabod could not be totally reassembled in Madrid. This complete view of the site, in its original environment, and showing later dwellings built in earthen architecture, is of remarkable interest. In addition, the quality of the plates lends itself to observation by virtue of a huge enlargement.

May this general view of the site of Dabod, surrounded by so many mud-bricks buildings now inundated by the Lake Nasser, be a call to use F. Teynard's *Album*.

CONCLUSION

Studying XIX^th^ century photographic views, especially those by F. Teynard, can provide valuable insights into the use of mud-brick in buildings and its evolution over time, mainly in six points.

1. Documentation of historical practices: As precisely dated documents, they showcase the use of mud-bricks in buildings, helping to understand the techniques, materials, and architectural styles employed since Antiquity.

2. Evolution of the use of mud-brick in construction: By comparison, it is possible to track the evolution of mud-brick construction methods, materials, and architectural designs. This can help to identify any modifications or alterations that occurred over time.

3. Preservation and conservation: Analyzing these calotypes can also provide insights into the preservation and conservation challenges associated with mud-brick buildings. It helps to assess how these structures have weathered over the years and whether any restoration or conservation efforts have been made.

4. Felix Teynard's contribution: The thoroughness of his work may contain unique insights into mud-brick construction in the Nile's region. Studying his photographs can shed light on the specific architectural features and regional variations in mud-brick buildings.

5. Cultural and social context: XIX^th^ century photographs often capture not only the architectural aspects but also the cultural and social context of the time. These photographs may reveal the roles of mud-brick structures in society, including their use for housing, infrastructure, or other purposes.

6. Comparison with modern practices: Comparing historical photographs with contemporary practices in mud-brick construction can help to understand how this traditional building technique has persisted or evolved in this region. It can also highlight any cultural or technological shifts.

The study of each calotype is in progress, and one substantial part is the collecting of basic documentation about the successive transformations of the sites. It is necessary to provide comparisons for each location, showing as much as possible its evolution until today, and any damage or restorations methods. Analyzing those calotypes, in an interdisciplinary approach, can provide help for the understanding of the use of mud-bricks in buildings in the Nile's region.

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[24] Frith F., *Egypt and Palestine photographed and described, vol. 1*, Londres, New York, James S. Virtue, s.d., digital publishing of INHA p. 134-137 and pl. 41-42 (https://bibliotheque-numerique.inha.fr/).

[25] CRES, Inv. Ph. Teynard N° 070, coming from *Dépôt légal Seine (1853)* N° 7900.

[26] CRES, Inv. Ph. Teynard N° 071, coming from *Dépôt légal Seine (1853)* N° 6942.

[27] Desroches-Noblecourt 1961, p. 29.

[28] CRES, Inv. Ph. Teynard N° 106, coming from *Dépôt légal Seine (1853)* N° 8489.

F. Teynard's *Album photographié* is extremely rare, the *Catalogue raisonné* written by Kathleen Stewart Howe and Catharine Roehrig is out of print (Stewart Howe 1992). The best way to facilitate a global access to the data, F. Teynard's calotype database, seems to be an open-access website.

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F. Teynard, *Égypte et Nubie : sites et monuments les plus intéressants pour l›étude de l›art et de l›histoire. Atlas photographié accompagné de plans et d›une table explicative servant de complément à la grande Description de l'Égypte. Première partie : Egypte, deuxième partie : Nubie*, Paris, Goupil et Cie ; Londres, E. Gambart and Co., 1858.

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MUDBRICK ARCHITECTURE FROM THE AVENUE OF SPHINX. AN OVERVIEW ON THE BUILDINGS' TECHNIQUES FROM TRENCH 4 AT SECTOR 5

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Egyptian Ministry of Tourism and Antiquities

SUMMARY

This paper explores the building techniques used to construct a series of mud brick features which date to the 21st Dynasty, recorded during a salvage excavation in an 80 x 4 x 4 m long trench excavated for a modern enclosure wall at sector 5 in the avenue of Sphinx (Fig 1).[1]

The sequence is archaeologically rich, comprising a series of mudbrick buildings overlying each other.
The area was excavated by hand and mechanically (when the stratigraphy does not show any trace of human activity). The observed Contexts were planned and recorded into pro-forma context recording sheets using the Single Context Recording System, and we use Geoffrey John Tessie & Lawrence Stewart Owens, *Standards of Archaeological Excavation; a Field guide to the Methodology, Recording Techniques and Conventions*, Egyptian Cultural Heritage Organization Monograph Series No.1, (Golden House Publications First edition – 2010) as our field guide manual. The archaeological team adapted the system to accommodate the fast pace of engineering activities. The stratigraphy of the excavation was recorded using a 'Harris' matrix.[2]

INTRODUCTION

The processional way between Karnak and Luxor temples was used as an avenue for sacred processions during the so-called Opet festival. The excavation process began in 1948 until the present time.[3]

There are indications that Hatshepsut at least paved a road between the two temples permeated by these six chapels.[4] However, Amenhotep III first instituted the sphinx-lined avenue between the tenth pylon and Mut temple. Although the sphinxes have been re-inscribed, re-worked and re-positioned many times by later kings. These paved ways linking the various temples of Karnak with one another and with Luxor temple were to remain very much as they were visualized. The present sphinx avenue between Karnak and Luxor temples dates to the reign of Nectanebo I.[5]

The Recent Excavation aimed to open the whole course of this great processional way; it began from 2005 in different sectors of the Sphinx Avenue[6] as a part of the Luxor City Master Plan. The excavations testify to a long history of occupations before and after this current phase. Therefore, in several parts of it, we can identify multiple layers that were once part of the ancient town of Thebes. In sector 5, which is located between Khonsu temple and Nectanebo I's avenue, a processional way of 120 rams were built. They bear the name of Amenhotep III but seem not to be in their original locations. They may have been installed here during the 21st Dynasty when the pylon of Khonsu temple was inscribed; this is contemporary with the mud brick buildings we will discuss here. The trench which we will discuss one of its phases is located at the southwest part of this sector at the area between the end of the rams in front of Khonsu temple and the sphinx's of Nectanebo I (Fig. 1).

---

[1] The team is composed of Mostafa Al-Saghir as Sphinx Avenue supervisor, Ali Hennawy as field director, Ahmed Altaher site supervisor, Ahmed Hasan as Archaeologist, Ahmed Hassan as site Surveyor and Aisha Mohamed as Ceramologist.

[2] Harris 1989.

[3] Abdul-Qader 1968, pp. 232-235; El-Saghir 1992, pp. 181-187.

[4] Cabrol 1995, pp. 23-24.

[5] Abd El-Raziq 1968, p. 157; Cabrol 2001, pp. 145-149 and pp. 283-296.

[6] Work sometimes was not at the same time on every sector.

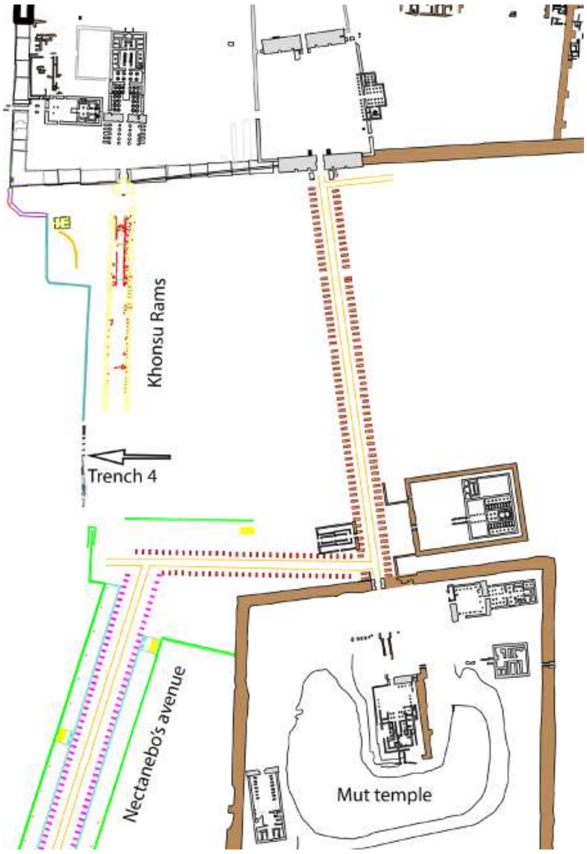

Figure 1: Plan showing trench 4 location.
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1. SUMMARY OF IDENTIFIED PHASES

It should be noted that the stratigraphic sequence of the phasing identified during the analysis of the data to date is entirely local to the area under discussion and does not reflect the 'true phasing' of the Sphinx Avenue. Similarly, and perhaps most importantly, it should also be noted that the area can still be considered 'under excavation', this phasing can only be considered interim and subject to alteration based on the findings of further excavations.
Stratigraphic analysis of the primary archive generated during the fieldwork has revealed at least 14 main phases of discrete activity in the trench area. Each one of the main phases has been further divided into sub-phase(s) (Fig. 2).

To simplify the activities only the 14 main phases can be shown on the following table:

PHASE #	Description
PHASE 01	EARLIEST Preconstruction of 21st Dynasty Wall
PHASE 02	STRUCTURAL – A construction of the 21st Dynasty building
PHASE 03	Dismantling of the 21th Dynasty building
PHASE 04	STRUCTURAL – Levelling Preconstruction of Mud brick undulating walls
PHASE 05	OCCUPATION A – A Levelling for floor construction
PHASE 05	OCCUPATION B – Floor construction
PHASE 06	STRUCTURAL – (Minor Remodelling)
PHASE 07	OCCUPATION – C
PHASE 08	OCCUPATION – D (Abandonment Interface)
PHASE 09	POST ABANDONMENT – (Mud brick collapse-Mass/Degradation and Erosion)
PHASE 10	STRUCTURAL – Settlement construction
PHASE 11	OCCUPATION A – Floors construction
PHASE 12	OCCUPATION B – Mud brick ovens construction
PHASE 11	POST ABANDONMENT – A (Primary Tumble/Demolition)
PHASE 13	POST ABANDONMENT – B (Mud Mass/Degradation and Erosion)
PHASE 14	POST ABANDONMENT – C (Modern Truncation/Disturbance)

Figure 2: List of main Phases excavated in the trench.
© A. Altaher

2. PHASE 2: CONSTRUCTION OF WALL IN THE 21ST DYNASTY

To explain the building techniques for the structure of the high priest of Amun and king Menkheperre of the 21st Dynasty in detail Phase 2 only will be discussed in the next part (Fig. 3: the five walls to the right).

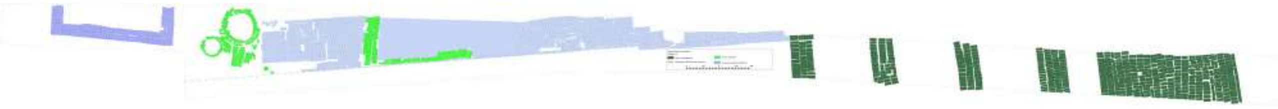

Figure 3: Plan show different phases on the trench.
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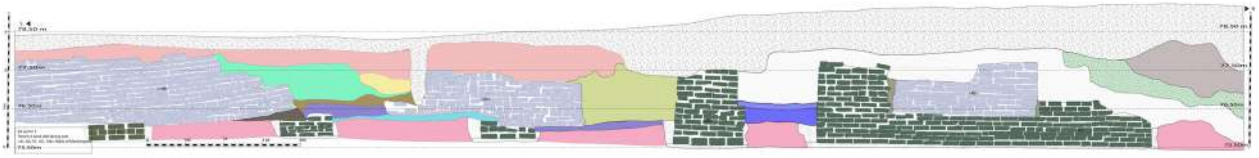

Figure 4: Section elevation of the northern part of the West section facing East on the trench.
© A. Altaher

This phase represents the construction activity associated with building a series of mudbrick walls, all running east/west. Its bricks were stamped with name of Menkheperre and includes the foundation cuts, walls foundation, the walls itself and the backfill of the foundation cut (Fig. 4).

The earliest deposit discovered (context (8)) within the trench covers almost all the excavation area.[7] Whilst still not fully excavated; this layer shows the abandonment phase that the site was exposed to between the different phases of use. It consists of silty sand with occasional ceramic sherds as a sequence of fairly homogenous deposits as dumped deposits or the result of Nile flooding in the area. So far, there is little strong evidence for the depth[8] or nature of the underlying sediments, making it difficult to determine accurate dating, although we tentatively suggest that they were formed at the end of the new kingdom and the beginning of the 21st Dynasty when the construction process began in the second phase at the site.

2.1 THE FOUNDATION CUTS

Here context (8) at phase 1 was truncated by five foundation cuts to build five parallel mud brick walls, these walls differed in their width, and therefore the width of each of their foundation cuts differed. Their cuts in plan are linear, with almost vertical sides and recorded ca 0.50 m deep, with a top elevation of ca. 76.05 m ASL.

From north to south, the general specifications for each cut were as follows:
- A cut with 9 meters' width was made for the first wall, located at the north end of the trench; the width of this wall is 8.5 meters. The filling distance between the cut edge and the southern face of the wall was 0.30 meters and 0.20 meters between the cut edge and the northern face of the wall.
- A cut with a width of 2.3 meters was made for the second wall, located at the south of the previous wall, the width of this wall is 1.8 meters. The filling distance between the cut edge and the southern and northern face of the wall was 0.25 meters.
-A cut with a width of 1.9 meters was made for the third wall, located at the south of the previous wall; the width of this wall is 1.4 meters. The filling distance between the cut edge and the southern face of the wall was 0.37 meters and 0.13 meters between the cut edge and the northern face of the wall.
- A cut with a width of 1.9 meters was made for the fourth wall, located at the south of the previous wall; the width of this wall is 1.42 meters. The filling distance between the cut edge and the southern face of the wall was 0.32 meters and 0.16 meters between the cut edge and the northern face of the wall.
- A cut with a width of 1.9 meters was made for the fifth wall, located at the south of the previous wall; the width of this wall is 1.4 meters. The filling distance between the cut edge and the southern face of the wall was 0.15 meters and 0.35 meters between the cut edge and the northern face of the wall.
- These distances, which were located between the edge of the cut and the wall, were reduced or increased due to the lack of straightness of the cut.
- In some instances, the upper edge of the foundation cut was wider than the bottom. As the edge of the cut angles toward the base of the foundation, creating a little narrower width, the edge, and the depositional sequence that the trench truncated were clearly visible in the trench's sides.

2.2 FOUNDATION LAYERS AND FOUNDATION COURSES

The bottom level which was needed to construct the modern wall in the trench was a good chance to expose the top of the foundations of the walls in order to see how they were constructed. To reach the bottom of the foundation cut a small sondage was excavated through the lower fill of the cuts to the base of the foundation cut. It revealed an identical stratigraphic sequence (foundation trench with a levelling layer of fine Nile sand added at the bottom of the cut) as a discrete preparation layer for the walls mud brick foundations.[9] This levelling was recorded in all the sondages excavated for the five walls.

Not all walls followed the same construction method for the foundation courses. In general, the foundations consisted of three to four courses depending on the topography of the cut bottom layer (the bottom elevation for five walls was almost the same). No mortar used between the preparation deposit and the first course.

On the thick wall there were three foundation courses, the first one was header then alternating courses of headers and stretchers offset sideways.

Two of four dividing walls (3 and 5) foundation bonding show alternating courses of headers and stretchers offset sideways. The first course was a header followed by a course of mud bricks with their stretchers running horizontally then the rest was alternating courses of headers and stretchers offset sideways.

For the second wall which is located directly to the south of the main thick wall (this is the widest wall of the four dividing walls (1.9 meter) the first course was on edge followed by a course where two faces are stretchers and the inside is a header. The third course was headers. The last course was similar to the second one.

For the fourth wall, the first course was header followed by two header courses then a stretchers course.

---

[7] Work stopped on this level because it is level needed for modern constructions.

[8] About 30 cm of it was excavated.

[9] Emery 2011, p. 2; Choisy 1904, pp. 21-41; Clark, Engelbach 1930, pp. 209-211; Goyon *et al.* 2004, pp.110 - 123; Spencer 1979, pp. 114 -116.

2.3 BONDING

Except for the thick wall and the wall to its south there are only a few courses left above the foundation courses. All walls were intentionally dismantled to be replaced by the next Phase, which also consisted of a series of mudbrick walls. From the data, it can be determined that the method of building these walls adopted the construction system of the upper courses from the beginning of the first course.

Fifteen courses survived from the thick wall (Fig. 5), following the standard Egyptian way for constructing the enclosure walls.[10] The wall consists of a central mass entirely of headers, whilst the outer faces exhibit alternate courses of headers and stretchers with carefully pointed joints, which would considerably speed up the process of construction.[11]

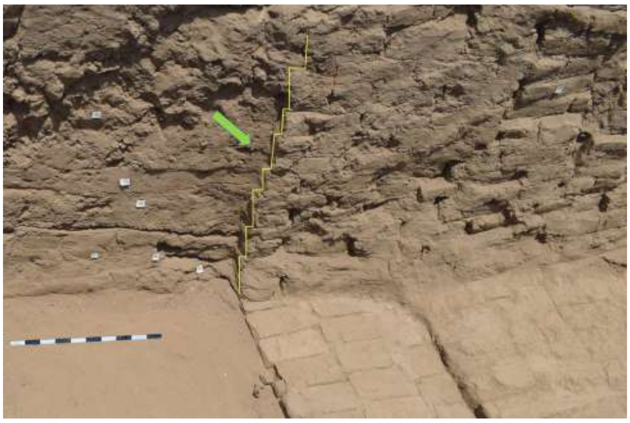

Figure 5: Wall's face slope, which produced by laid the bricks stepping each layer of bricks back slightly.
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Like the usual technique of building the thick walls in ancient Egypt The face of the wall has a noticeable slope toward the center; it is produced by stepping each layer of bricks back slightly, and then smoothing the surface with plaster.[12]

Another technique of making the slope was by laying the bricks at right angles to the slope of the face. This method makes the courses assume the form of a concave arc through the thickness of the wall.[13] This technique of making the slope is rare.[14] Some irregularities can occur in central mass of such large structures, for example in our wall some of the bricks in the central mass were laid down as stretchers, due to the brick rows within the central mass being poorly organized resulting in some bricks having to be laid as stretchers to adjust the bricks within the central mass. In addition, some bricks were required to be laid on their edges, as a deliberate technique of adjusting the levels of the courses. This process was not restricted to thick walls and can be found everywhere in Egyptian brickwork (Fig. 6). In addition, some bricks are tilted over to raise one section of a course more than another does. Further adjustment of the levels was made by varying the thickness of the mortar in the horizontal joints, but careful mortaring is only found on the exterior surfaces of the walls.[15] As Spencer mentioned,[16] it is interesting to note that the Egyptians themselves decided that all walls of this kind were to be composed entirely of headers internally, as shown by some references in the Harris Papyrus to the construction of temple enclosures by Ramesses III. It is recorded that the king had a wall of twenty DADA.wt built around the temple of Hermopolis, DADA.wt being, quite literally, the Egyptian word for headers.[17]

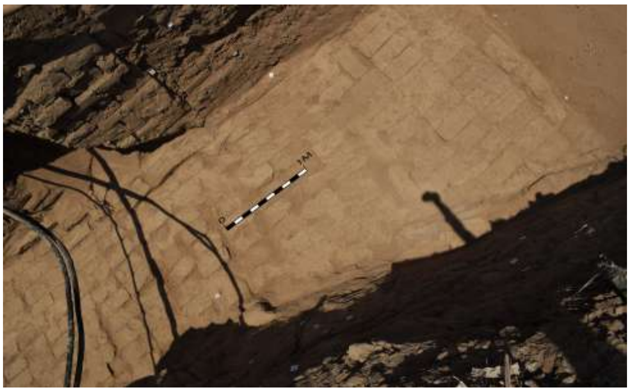

Figure 6: Bonding technique in the central mass at thick wall of Menkheperre.
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No wooden beams or reed matting seem to have been included in the structure of the wall. The wall is incline about 6 cm in the 3 meters we excavated (this is the width of the trench) which means that there is possibility that it is an undulating wall.

The width of the wall to the south is 1.8 meters. The foundations consist of three courses with another three courses built above them keeping the same width. Above this, the north face (only) backed off by 20 cm, which reduced the wall width to 1.6 meters. The bonding was comprised of alternating courses of headers and stretchers (Fig. 7).

On the three other dividing walls (3, 4, 5) two to three courses survived. The bonding technique was alternating courses of headers and stretchers. Here the wall did not consist of a central mass constructed entirely of headers but rather each course was either header or stretcher from the face through the core to the other side (Fig. 4).

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[10] The north face was much more decayed with more mudflows see Spencer 1994, p. 319, Fig. 3.

[11] Arnold 2003, p. 36; this is A2 bonding according to Spencer 1979.

[12] Spencer 1979, pp. 113-114; this technique was also used in some later walls at the trench.

[13] Spencer 1979, p. 70.

[14] Like some parts of the Great Girdle Wall of Ramesses III's temple at Medinet Habu, Hölscher 1951, p. 3, pl. 41; Kemp 2000, p. 91, Fig. 3-13c

[15] Spencer 1979, pp. 113-114, Fig. 74.

[16] Spencer 1979, p. 116.

[17] Spencer 1979, p. 116.

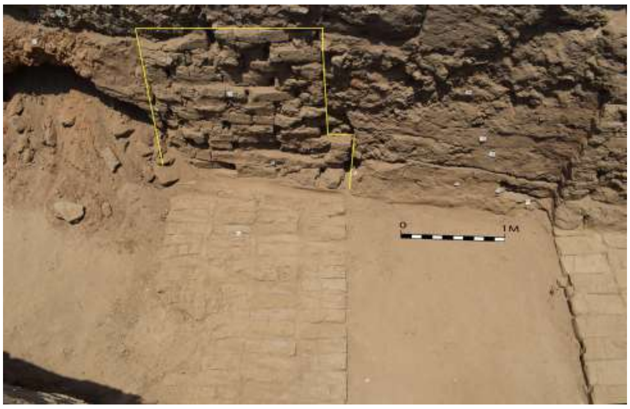

Figure 7: Wall its six lower courses wider than the rest.
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2.4 THE MORTAR

The mortar was typical for all five walls, being composed of light brownish grey clayey silty mixed with Nile sand. Straw is occasionally found and inclusions, such as small pebbles and ceramics, can be detected as well.[18] The mortar normally forms a bed beneath each new course of bricks and between each brick. On the thick wall, the size of the vertical bed ranged between 0.01-0.04 meters while the horizontal bed ranged between 0.02-0.05 meters (Fig. 8).

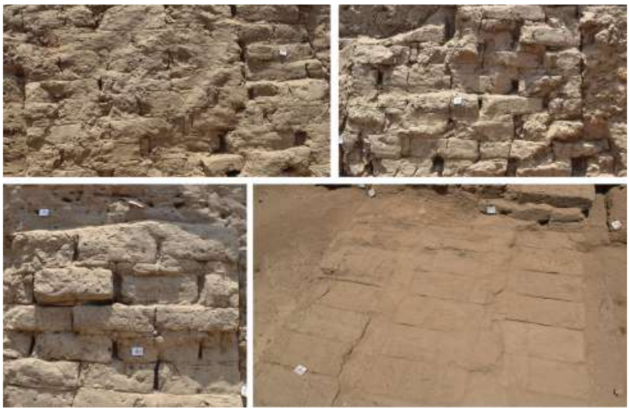

Figure 8: Mortar, bricks composition and size with details of the vertical and horizontal beds.
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On the bed mortar of the four dividing walls, the size of horizontal joint ranged between 2-5 cm, same as the thick wall. On the vertical bed where the course is header aligned the bed measures 0.06-0.09 meters between bricks depending on the size of the brick: when the brick is 43 cm the joint is usually around 0.06 meters, while with the 0.41 meters brick, the joint usually is 8-9 cm. The possible reason for that is if the bricks were to be placed on a normal bed size, then the width of the wall would be smaller than the proposed size; so, by leaving a big space between the bricks the desired width can be achieved. On the stretcher course the brick width was enough to provide the proposed width, the beds are of a normal size, and the wide beds underneath are covered (Fig. 8, lower right).

2.5 BRICKS COMPOSITION AND SIZE

The majority of the bricks are dark grayish-brown in color. Their composition more generally shows a moderate to high percentage of Nile clay mixed with silt and coarse Nile sand (Fig. 9).[19] They fall within the parameters of standard Karnak mud bricks.[20]

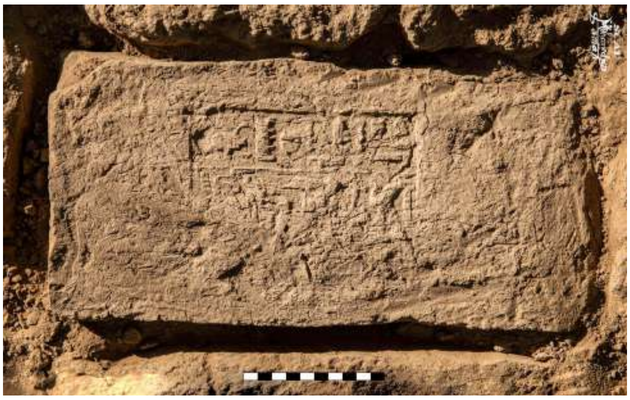

Figure 9: The bricks and their composition of Nile clay mixed with silt and coarse Nile sand.
© M. Samah

Organic materials like straw can be identified easily, although sometimes it can be attested only by the impression left by these materials. The addition of straw to the original mud clay enhances the brick strength three times more than its original value than without.[21] Moisture seems to have destroyed much of the organic content in the bricks.[22] The bricks also contained a wide variety of non-organic inclusions such as small pebbles, ceramics and small volcanic rocks that came with the Nile flood. Mud-brick structural integrity indicates that the variety of material components added to mud bricks sustained their strength.[23] The sand provides strength; the fine sand is a filler to lock the grains of aggregate, and the silt acts as a binder and plastic medium to glue the other ingredients together. Soil structures with a high percentage of sand may be stronger when it dries, but they are more vulnerable to erosion from rain. Soil structures high in clay may be much more resistant to water and erosion, but less strong.[24] Concerning our bricks, the composition seems not to be well mixed resulting in several clearly identifiable cracks caused by the unmixed clay soil in the composition.[25]

Two sizes of brick are present in the construction: 0.41 x 0.19.5 x 0.13 and 0.43 x 0.18.5 x 0.12 meters. They appear in the wall without any regulation between courses; sometimes both are used in the same course. Many of the bricks are stamped with name of Menkheperre in two forms;[26] these forms will be discussed in detail below.

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[18] Yamamoto, Creasman 2020, pp. 401-402.

[19] Arnold 2003, p. 34.

[20] Kemp 2000, pp. 80-83.

[21] Hassaan 2017, pp. 11-16.

[22] López-Arce, García-Guinea 2005, pp. 929-941.

[23] McHenry 1984, p. 48.

[24] Boozer 2015, p. 11.

[25] Lacovara 1984, pp. 20-27.

2.6 FOUNDATION TRENCH BACKFILLS

After the walls had been constructed, the foundation trench was backfilled with a deposit of Nile sand, some mud brick fragments were found occasionally in this back fill, it is interesting also to find some complete bricks. These may have been spillage from the builders in the foundation trench during the building process (Fig. 10).

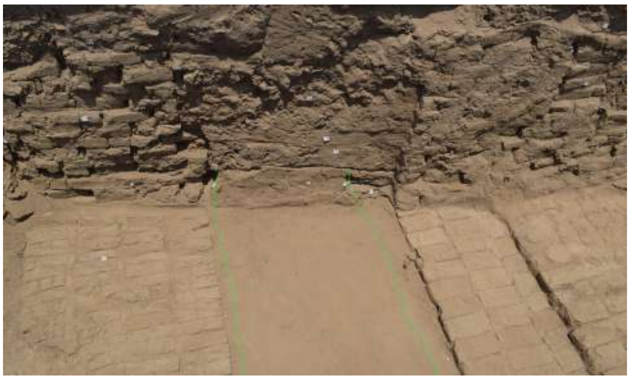

Figure 10: Showing the limits of the foundation trenches and the backfill for the wide wall and the wall to its south.
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3. DISCUSSION

The high priest and king Menkheperre was a son and second successor of the high priest of Amun, Paynodjem I who held the office for some thirty years during the second half of the 11th century BC,[27] and is well known from the stamped bricks he has left scattered throughout Upper Egypt.[28] In fact, his tenure of office was marked by an ambitious fortification program in which such "strong points" as Gebelein, Kom esh-sheikh Mubarrak,[29] and especially the headquarters of Upper Egyptian administration at El-Hibeh.[30] All received restored circumvallation.[31] His predecessors certainly neglected to maintain institutions like the temple of Amun, which in turn resulted in it suffering squatter settlement within its sacred precincts. At any rate, in the 40th year of a king who is probably Psusennes I, "inspection of the House of Amun-ra (was made) by the First Prophet of Amunra, Menkheperre" [32] and quite possibly pursuant thereto, but after a delay of eight years, Menkheperre could formally commemorate "the start of the work, a new execution, in the House of his father Amun-re"; he built the very great wall[33] on the north of Karnak.

Stamped bricks from his reign are found in many places at Karnak[34] and on the south wall of the Osiris catacomb.[35]

At the Sphinx Avenue a stamped red brick with his name was also found reused in a structure at sector 2.[36] In 1993, others were found in a sandstone structure in the area of Abu El-Gud, 75 m east of the Sphinx Avenue.[37]

On the dromos it was essential to extend the clearances to define its end point. The goal was to know whether, as is the case for the western dromos of the temple of Amun, that of the northern temple of Montu, or those of Tod and Medamoud, that the sacred aisle of Khonsu ended in a quay and a lake. Since the work of Chevrier in 1947, and following the verifications carried out in 1980 by the CFEETK, it was known that, unlike the aisle linking the 10th Pylon to the temple of Mut, it was not used to connect the temple of Khonsu with the sacred avenue leading to Luxor in the south.[38]

Those excavations stopped at a mud bricks wall(s) representing the southern side of the dromos. These were not described in the excavation reports of 1982-1983. During our excavation of the trench, we were unable to examine it clearly due to its presence under layers of modern rubble, but the size, specifications of the bricks, and the method of construction are the same as the phase of Menkhererre. The decision was made to leave the area for future excavations after the completion of construction work. Our preliminary findings suggest that Menkhererre erected an enclosure of wavy wall(s) in front of the dromos which was adjoined by other mud brick walls, and that these buildings were part of the original planning for the establishment of the rams in front of the Khonsu temple.

During the cleaning on the forecourt of the Opet temple loose blocks, lintels and frames dating back to the reign of Thutmose III were brought to light. Several of these mention Menkheperreseneb, some in an unusual way in the context of a religious domain such as the temple of Karnak.[39]

In addition, other loose inscribed blocks in his name combined stone door frames of brick architecture had been suggested that come from a monument devoted entirely to Menkheperreseneb who had all of his titles carved there.

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[26] It sometimes becomes possible to track construction phases, not only between reigns but also within reigns as stamp types changed (Emery 2011, p. 7; Harvey 1998, pp. 190-206, Figs. 34-36; Hayes 1951, pp. 162-164, Figs. 24, 30; Leahy 1978, p. 46.

[27] Kitchen 1973, pp. 269 -272.

[28] Jansen-Winkeln 2007, pp. 80-81, no. 18.

[29] Wainwright 1927, p. 76.

[30] Lull 2009, p. 242, Fig. 3.

[31] Ritner 2009, p. 124; Beckerath 1968, pp. 7-36.

[32] Karnak annals: Legrain 1900, p. 53.

[33] Sbty wr, on which, see Meulenaere 1953, p. 96; Yoyotte 1953, p. 35.

[34] Overview: Redford 1977, pp. 17-18.

[35] Coulon *et al.* 1995, p. 221; Leclère 2010, p. 260, Fig. 12 (*ḥry(t) wrt ẖnrwt n Jmn ꜣst-m-Ḫbyt* type).

[36] Boraik 2013, p. 17, Fig. 6.

[37] Boraik 2013, p. 17, Fig. 7.

[38] El-Molla et al. 1993, pp. 239-262.

[39] Valbelle, Laroze 2010, p. 409.

There are no related bricks found during this excavation, which indicate an alternative origin. These elements probably came from the building we exposed in the trench. A hypothesis like this can only be proved by further extension of the excavations in the area to the east of our trench.

The two key requirements in temple construction were of course raw materials and labour, the latter including both skilled and unskilled workers. A proportion of the materials used in construction would have been available locally and required little more than unskilled labour to procure clay and straw for the thousands, sometimes millions, of mudbricks needed for enclosure walls and other architectural elements. Wood for scaffolding,[40] ramps, doors and roofing, and other materials used in construction (sand, plaster, paint) would also have been required, as well as tools and equipment.[41]

Even as today, mortar would have been mixed as close to the construction site as possible, whereas bricks more often were produced at a greater distance from the construction site and transported at least a short distance (as pictured in the brick-making scenes from the tomb of Rekhmira.[42] Redford suggests that East Karnak was, during the 10th century BC, the site of a brickyard where the bricks were made. This being a precursor to the brickyard present in the 17th century AD in the village of Nag-el Fokani, just across the Chevrier's drainage ditch.[43] Whilst some bricks were stamped, the majority were left plain. At the temple of Thutmose III in Thebes, for example, the archaeologists estimated that only 25–30 percent of the bricks bear stamp impressions.[44] Generally more than one design of mud brick stamp was used by the high priest,[45] for our walls two different stamps were used. The first one is rectangular and divided into 2 columns: 1- Hm NTr tpy n Imn Mn-xpr-Ra, 2- Hr.yt xnr.t wr.t n Imn As.t-m-Xb.yt. The majority of the stamps were of this type. The second is represented by two cartouches beside each other: Hm NTr tpy n Imn on the left and Mn-xpr-Ra to the right (Figs. 9 and 11). Papyrus Reisner I provides details of day-to-day progression of temple construction.[46] An early Ptolemaic papyrus illustrates how brick deliveries were carefully monitored, and that thousands of bricks for one magazine-building project were coming from various sources, including a farm.[47] The two different stamps may indicate two different sources or at least two working groups at one place.

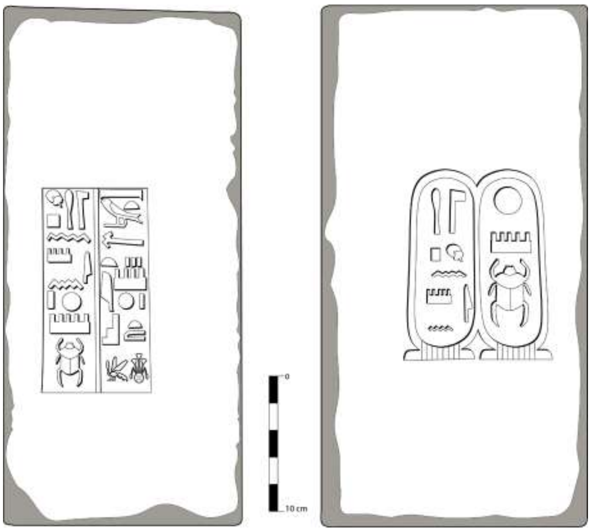

Figure 11: The two different stamps used in the walls.
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CONCLUSION

The buildings of Menkhererre located at the front of the dromos in front of the Euergetes Gate are one of the few examples that remain in a good state of preservation within the Theban area. Taking a deep look at the construction techniques of these buildings has helped deepen our understanding of the strategies for building official mud-brick buildings of that period. Using two forms of stamp in these buildings is not common. Although the nature and functions of these buildings are not completely clear, the preliminary evidence indicates that these buildings are directly related to the dromos, as it was within its original planning. Probably it provided a sacred space for the commoner's access to be near even from the outer stonewalls of the temple.[48]

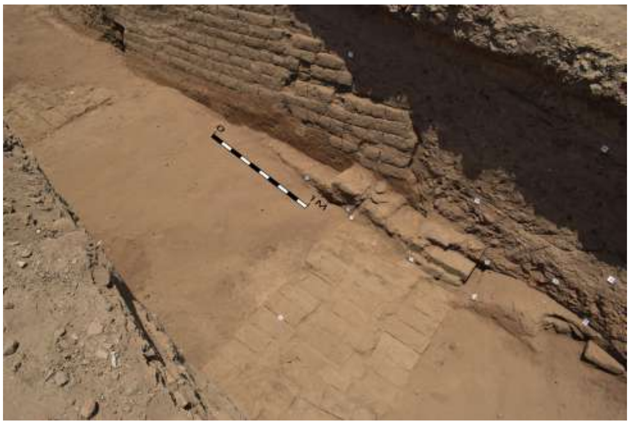

Figure 12: Structure of the 21th Dynasty dismantled and another undulating walls built direclty on them.
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[40] Kemp 2000, p. 88.

[41] Spencer 2010, p. 474.

[42] Davies 1943, pl. LVIII-LIX; Kemp 2000, p. 92.

[43] Redford 1977, p. 18.

[44] Álvarez, Campuzano 2015, p. 65.

[45] See Jansen-Winkeln 2007, pp. 78-81; Ritner 2009, pp. 135-136.

[46] Simpson 1963, pp. 53–85.

[47] De Cenival 1984.

[48] Galal 2013, pp. 159-162.

These buildings continued to function probably until the 30th Dynasty, when the Sphinx Avenue was constructed between Karnak and Luxor, so the priest buildings of the 21st Dynasty were deliberately removed and replaced with other buildings that differed slightly in planning (Fig. 12). The space available for the excavations was not sufficient to form extensive information about the area that precedes the rams, and it was decided to leave this area for more organized future excavations. Further excavations will undoubtedly expand on our understanding of this area and help to answer many of the questions related to this rationale.

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SUB-THEME 1.3 - BUILDING TECHNIQUES, PRACTICES AND KNOW-HOW IN THEIR HISTORICAL, ENVIRONMENTAL AND CULTURAL CONTEXT

ANOTHER BRICK IN THE WALL: FIRST ARCHITECTURAL RESULTS OF THE STUDY ON DENDARA'S WALLS

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SUMMARY

Pearl of the Greco-Roman architecture in Egypt, the temple of Hathor at Dendara is one of the best preserved monuments of its kind. Built during the reign of Ptolemy XII (1st century BC), it was concealed behind an enclosure wall whose undulating courses form an ocean of mud bricks around the temple, protecting Hathor's domain. This monument is today largely understudied: its mass discourages both detailed studies and conservation attempts. Although slowly collapsing since its abandonment, its deterioration rate is now accelerating due to recent local environmental changes. In response to these alterations, the *Institut français d'archéologie orientale* (IFAO) mission at Dendara has initiated a study and conservation program. Encouraged by the Egyptian *Ministry of Tourism and Antiquities* (MoTA) in collaboration with the *Centre Franco-Égyptien d'Étude des Temples de Karnak* (CFEETK) and supported by the *Ministère de l'Europe et des Affaires Étrangères* (MEAE), the first season was conducted in Autumn 2021. The standing structures and the details of their constructivon have been carefully documented in order to replicate them with accuracy during the conservation process. These also form the basis of the architectural study of the structures, the first results of which are presented here.

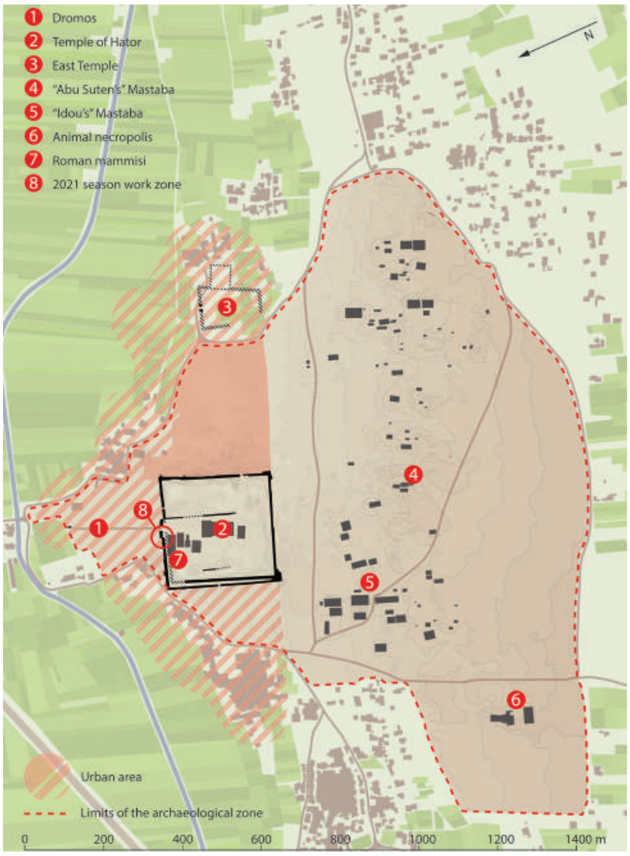

Figure 1: Dendara, site plan
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INTRODUCTION

A small village on the desert edge close to Qena (Upper Egypt), some 50 km north of Luxor, Dendara[1] has declined in significance over time. Its modest appearance of today is, however, deceptive... it was once a metropolis of national importance. Capital of the Tentyrite nome, its existence as a cultic centre is documented since at least the Old Kingdom[2]. Human occupation, however, goes back much further[3] and continued uninterrupted through to the medieval period[4]. The archaeological zone contains the ancient city, the necropolis and two cult complexes rich in monuments that include the Temple of Hathor, whose construction began during the reign of Ptolemy XII (80-58 and 55-51 BC) (Figs. 1 and 2).

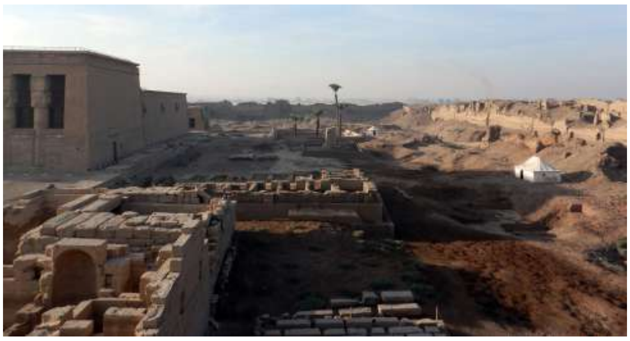

Figure 2: View of the site facing south, taken from the roof of the Roman Mammisi. On the left side of the picture, the temple of Hathor. The enclosure wall runs from the right side to the horizon.
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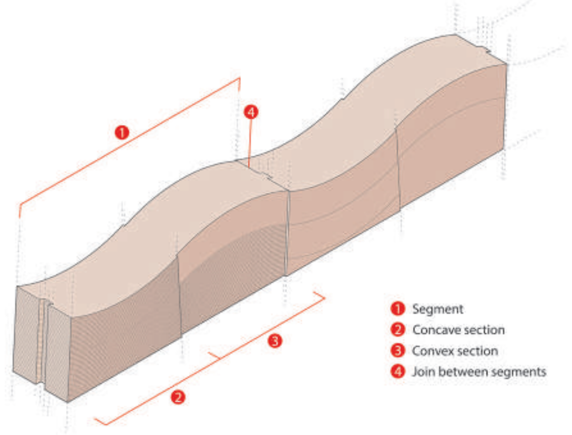

Figure 3: Walls with undulating courses, principle diagram.
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The enclosure wall of the temple is one of the most imposing remains on the site. With a length of over one kilometre, a width of about ten metres and a preserved height reaching twenty metres, it almost entirely conceals the main temple. This massive structure is made up of mud bricks assembled with *mouna* (mud mortar) using a construction method that was unique to Graeco-Roman Egypt: the courses are not horizontal, but undulating[5] (Fig. 3).

1. PURPOSE AND METHODS

Despite their mass, these walls are somewhat fragile. When the precinct was cleared[6], the enclosure was deprived of the surrounding deposits' protection, and has been gradually deteriorating ever since. The rise in the water table resulting from the development of neighbouring crops has also accelerated its decline over the last decades. A study and conservation program was therefore initiated by the *Institut français d'archéologie orientale* (IFAO) mission in Dendara[7] with the support of the *Ministère de l'Europe et des Affaires Étrangères* (MEAE) and in collaboration with the *Ministry of Tourism and Antiquities* (MoTA). The first campaign[8] was held in Autumn 2021.

The work focused on the main access to the precinct (Fig. 1 feature 8). Here, the enclosure wall presents an extension whose plan reminds – in negative – the configuration seen on either side of the first pylon at Karnak. This protrusion probably belongs to a portion of the enclosure rebuilt under the reign of Tiberius[9] (14 – 37 AD) before the erection of the Roman *mammisi* (birth temple). A large part of the junction between this feature, which marks the entrance to the precinct, and the north face of the enclosure wall was levelled below the present ground level. Excavations were therefore initiated to find the original geometry of these structures.

After the excavation of the archaeological layers still *in situ*, the wall was cleaned, and the elements too damaged to be conserved documented and removed. Photogrammetric surveys, technical drawings and photo-documentation have been completed during the process, so that the state of the whole monument is recorded before the conservation begins.

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[1] For a presentation of the site, see Daumas 1975.

[2] The necropolis was already active during the IVth Dynasty (see Petrie 1900, p. 2).

[3] Recent work led by G. Marouard and Y. Tristant at Dendara has confirmed the Early and Pre-dynastic origins of the site (see Marouard 2019, Tristant 2022, Tristant (in press)).

[4] See for instance Zignani *et al.* 2021, § 4.

[5] This building method has been the subject of several studies. See, for instance, Spencer 1979, pp. 114-116. See also Golvin *et al.* 1990 for a general synthesis based on Karnak, Beiersdorf 2015 regarding Heliopolis and Vanpeene 2022 for Dendara. The purpose of this complex technical solution is unclear. Some Egyptologists have suggested a symbolic explanation (see for instance Pirelli 1999), while others put forward technical reasons (see Golvin *et al.* 1990).

[6] The clearing of the site began in the 19th century (Zignani 2011, p. 43). It was completed before E. Chassinat started the epigraphic recording of the main temple, in the beginning of the XXe century (Chassinat 1934, pl. I-XXX).

[7] More information about the mission and its activities can be found in the annual online reports. See for instance Zignani *et al.* 2022.

[8] The significance of the enclosure was highlighted as early as 2015 by the IFAO mission in a collaboration with the Oriental Institute of the University of Chicago (See Marouard 2016, p. 12). The walls of Dendara were also part of the PhD material of O. Siegel, then student at the University of Chicago under the supervision of N. Moeller (see Siegel 2020)

[9] See Marouard 2016, Fig. 5.

This work allowed the identification of several phases of secondary occupation that developed on and against the enclosure, which were the subject of a first presentation given during the Nile's Earth project's kick-off conference[10]. This second presentation will focus on the preliminary results of the architectural analysis. Indeed, the cleaning process facilitated the observation of the details of the internal construction of the masonry and the reconstruction of the building methods used – essential preliminaries to the conservation process. It also led to the discovery of previously unknown internal spaces in the wall that will be integrated into the reconstruction project.

2. CONSTRUCTIVE OBSERVATIONS

This was an opportunity to study the building methods, so that not only the shape, but also the internal organization of the masonry could be replicated. Special attention was paid to the brick coursing pattern, but many other details were also noted, such as openings and reinforcements in wood or stone, all which had to be taken into account during the conservation process.

2.1 BRICK COURSING PATTERN

The bricks used to build this section of the wall are 36 cm long, 17 cm wide and 9 cm high[11], and are laid exclusively in headers in the masonry core[12] (Fig. 4 feature 1). This arrangement probably makes the structure more flexible and increases its strength[13]. The facings alternate layers of headers and layers of stretchers. This pattern was also employed for the internal facing on both sides of the joint between each segments of the wall (Fig. 3 feature 4), which would tend to confirm that each of them is designed as an independent unit.

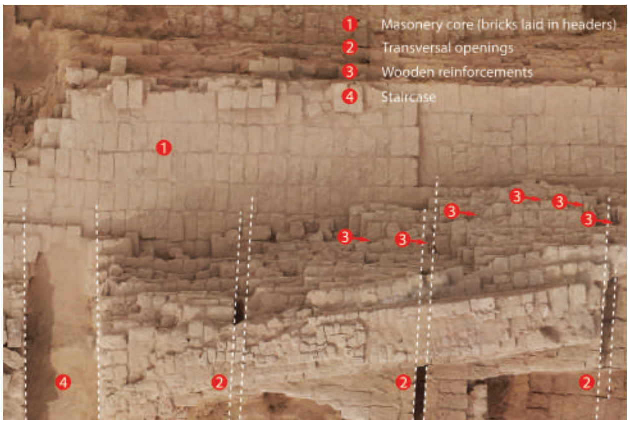

Figure 4: Extract of the photogrammetric survey of the wall after cleaning.
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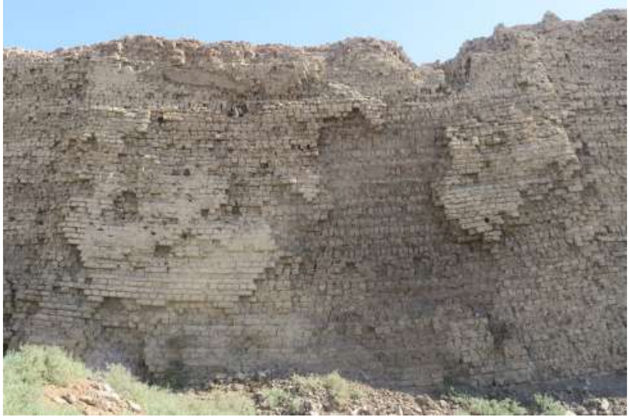

Figure 5: View of one of the wall sections nearby the eastern gate. The facing is damaged and shows layers of mud bricks on edge.
© Mission archéologique de l'Ifao à Dendara, M. Vanpeene

Though the facings did not show it at all, courses with bricks laid on edge were occasionally present in the heart of the masonry. This peculiarity was first observed during the excavation of the wall's foundation levels. Examination of other sections where the facing was damaged revealed similar courses laid regularly throughout the structure (Fig. 5). The presence of these atypical courses could be explained by the way the bricks were assembled. Two systems coexist:

- The facings are assembled regularly with *mouna*. The courses are separated from each other by carefully-made horizontal joints, the thickness of which varies very little (2.0 to 2.5 cm). Within the same course, the bricks are separated from each other by a very thin vertical joint whose filling – when present – penetrates no more than a centimetre into the masonry, as if set from the outside. This mortar has often fallen out over time, leaving the joints open (Fig. 6).

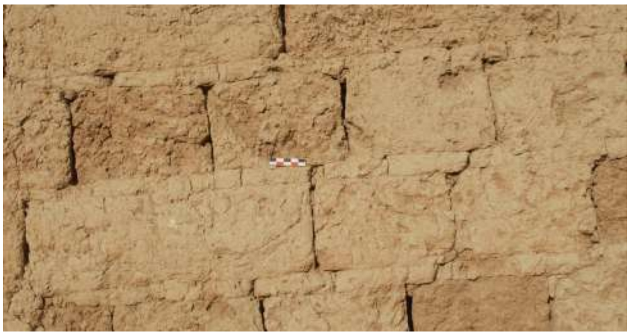

Figure 6: Detail of the facing: the horizontal joints have an even thickness of about 2 cm, while the vertical ones are much thinner.
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- In the heart of the masonry, the laying is more approximate. The courses are separated by a very irregular layer of *mouna*. Coarsely spread, it is thinner overall than the horizontal joint of the facing, as if it had been "stretched" to save time or material. Bricks of the same course were juxtaposed without jointing, probably for the sake of efficiency[14]. In some places, it even appears that the masonry core was assembled without any mortar at all (Fig. 7).

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[10] M. Vanpeene, "Waves upon Waves of Mud Bricks to Protect Hathor, A Study of the Enclosure Wall of Dendara", conference given online on 22nd September 2022.

[11] One can note an almost 1:2:4 proportion, providing constructors with infinite rational bounding combinations.

[12] This is the case for all the other contemporary examples that have been published. See, for example, Golvin *et al.* 1990, p. 919 for Karnak, and more generally Spencer 1979, p. 116.

[13] This hypothesis is often formulated in scientific literature. See for example Spencer 1979, p. 113. The use of flexibility in the apparently monolithic structure of Egyptian monuments has been demonstrated in other cases, see for instance Zignani 1996.

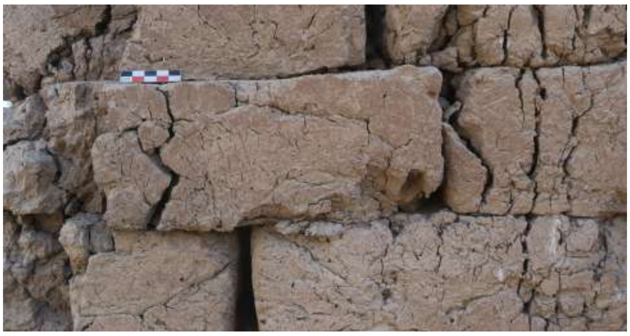

Figure 7: Detail of the masonry core: the bricks are sometimes assembled without mouna.
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The coexistence of these two systems leads to an imbalance between the growth rate of the facing and that of the masonry core, which was observed during conservation operations. Without correction, it leads to increasingly concave cross-sections, until eventually construction is no longer possible. Edge-laid brick courses were used to compensate for this phenomenon[15] (Fig. 8). They change the cross-sectional curvature of the courses, which become horizontal or slightly convex, before becoming concave again as the structure rises[16]. The regularity of their appearance varies over the different sections of the wall: they are found every four courses in the section north of the eastern Gate[17], whereas their occurrence is much more irregular west of the precinct; they are almost absent in the area currently being conserved. This irregularity shows variations in the quantity of *mouna* used, perhaps linked to different phases or different building teams.

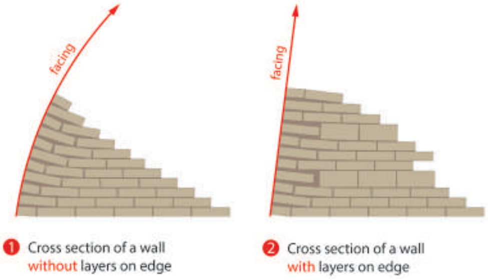
facing
facing
❶ Cross section of a wall without layers on edge
❷ Cross section of a wall with layers on edge

Figure 8: Use of bricks on edge in the masonry core, principle diagram.
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Despite these internal variations, the aspect of the masonry is remarkably regular, forming a massive apparently indestructible structure[18]. The construction featured a series of details apparently designed to increase its longevity, such as long transversal openings.

2.2 TRANSVERSE OPENINGS

A group of small ducts built in the masonry core and running right through the wall have been observed (Fig. 4 feature 2). Around 35 cm high (three courses) and 11 cm wide, these openings form rows that extend around the entire perimeter of the wall. Observation of the preserved sections at the south-west corner of the temple suggests that at least two rows of openings have been superposed. It's possible that this pattern, which visually emphasizes the curvature of the courses, was repeated all the way up to the top of the wall.

The purpose of this detail, also attested at Mirgissa[19], is as yet unknown. It could have been part of the fixing of a scaffolding system. A.J. Spencer also suggests that it may have been a device to ventilate the structure's core[20]. By drying out the masonry, such a device could additionally help limit the growth of intrusive vegetation. Controlling the humidity of the masonry may also have helped to preserve the transversal wooden reinforcements included in the structure.

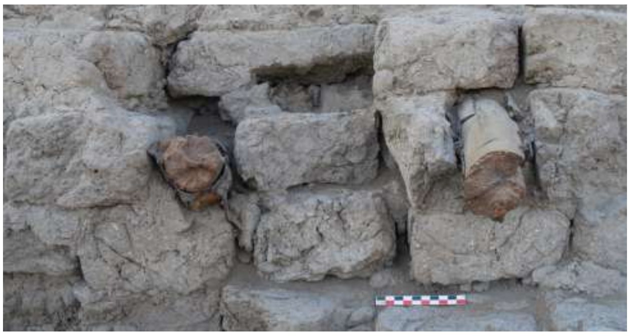

Figure 9: Wood reinforcements in the masonry.
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2.3 WOODEN REINFORCEMENTS

These elements – the trunks of small trees used raw and measuring between 6 and 15 cm in diameter – go right through the wall (Fig. 4 feature 3, Fig. 9). They are placed as construction progresses, sometimes causing minor irregularities in the brick pattern. These reinforcements can be found in other enclosure walls, such as those at Karnak[21], Mirgissa[22] and Tebtynis[23] where these elements are visible on the facade.

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[14] This hypothesis has been formulated already for Karnak. See Golvin *et al.* 1990, p. 919.

[15] The use of bricks laid on edge has often been noted in Egyptian construction, but generally as a timely adjustment procedure (see Spencer 1979, p. 114), and often at the base of a wall. It is here a system, where these layers are repeated more or less regularly in the masonry.

[16] The synthesis published by J.C. Golvin and colleagues mentions a system of curves and counter-curves at Karnak (see Golvin *et al.* 1990, pp. 929-930) which was not observed at Dendara.

[17] Specifically, on the part of the wall that G. Marouard dates to the Late Period (Marouard 2016, Fig. 5).

[18] The obsession for eternity is an important aspect of the ancient Egyptian architectural culture. See for instance Zignani 2011, pp. 313-314.

[19] See Dunham 1967, pl. LXXXIII a et b, and p. 157.

[20] See Spencer 1979, p. 116 and pl. 49a and b.

[21] Golvin *et al.* 1990, pp. 919-920.

[22] Dunham 1967, pp. 156-157.

[23] Rondot 2004, p. 10

Evenly spaced, they contribute to the aesthetics of the monument and emphasize the curvature of the courses. At Dendara, they stop just before the facing and are normally invisible, but the very poor state of preservation of the wall in our working area allowed them to be observed inside the masonry. Spread over three courses, the distance between them varies between 0.80 m and 1.30 m. At Karnak, longitudinal wooden reinforcements and *halfa* (*Desmostachya bipinnata*, a common plant that grows on the desert edge) mats are also found in the masonry[24]. Neither has yet been observed at Dendara, but the presence of stone reinforcements is noteworthy.

2.4 STONE REINFORCEMENTS

One of the special features of the entrance to the precinct is the presence of stone reinforcements set into the mud brick masonry.

The most imposing and distinctive of these is the one protecting the western corner of the wall (Fig. 10 feature 1)[25]. In plan, this element forms an L-shaped casing measuring 1.84 m by 1.30 m and varying in thickness from 0.42 m to 0.46 m. Its maximum preserved height is 2.23 m. The presence of dressed *joint surfaces* (with *anathyrosis)* against the mud brick masonry suggests that at least some of the blocks come from an earlier structure and have been reused.

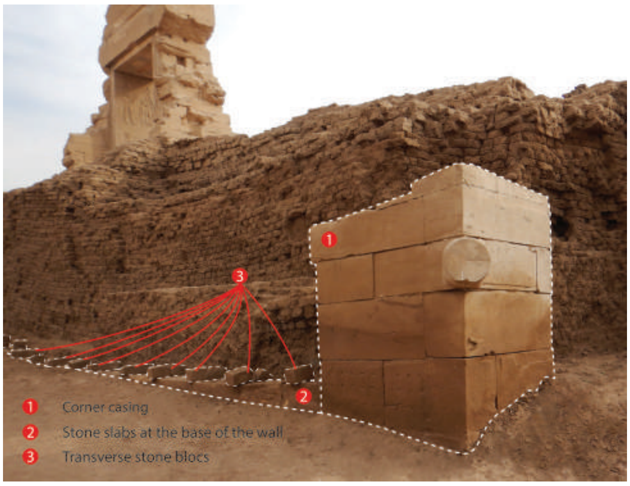

Figure 10: Stone reinforcements in the wall.
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This element has coarse joints – sometimes over 2 cm thick – filled with pinkish lime mortar, probably including some crushed brick or ceramic. Light cleaning revealed four courses of red bricks laid on edge under the stone structure. The foundations of the brick wall seem to continue under the stone reinforcement and further to the west, as if the original structure had been cut, refaced and reinforced. This hypothesis would be consistent with the peculiarities of the brickwork layout in the masonry core; but more extensive excavations will be required to confirm it. Such reinforcements are relatively common in ancient Egyptian architecture. There are many parallels to be found both in civil and monumental constructions[26], including at Tebtynis, where the northeast corner of the precinct was faced in stone several times over[27].

The stone reinforcement also includes a row of sandstone slabs at the base of the wall (Fig. 10 feature 2). These elements form a facing of 18-25 cm thick and 1-1.50 m long. They protected the base of the masonry from damage caused by capillary action. The curvature of this row of stone blocks does not exactly follow that of the mud brick courses. This and the presence of an empty space filled with debris between the slabs and the brickwork could indicate that these elements were set up after the construction of the wall as part of an ancient consolidation operation.

One row of stone blocks immediately above the stone slabs is also of note (Fig. 10 feature 3). Each has an almost square section – 14 to 18 cm – and measure approximately 50 cm in length. Most of them are fractured and some have been restored by inserting cement-sealed metal pins. These interventions are obviously modern, implying that the blocks are probably not exactly *in situ*. However, archival photos (Fig. 11) found in the *Centre Franco-Égyptien d'Étude des Temples de Karnak* (CFEETK)[28] collections confirm that these elements were already present at the time of the first conservation work in the early 20th century. They were therefore part of the ancient structure before this intervention, which only slightly altered their position.

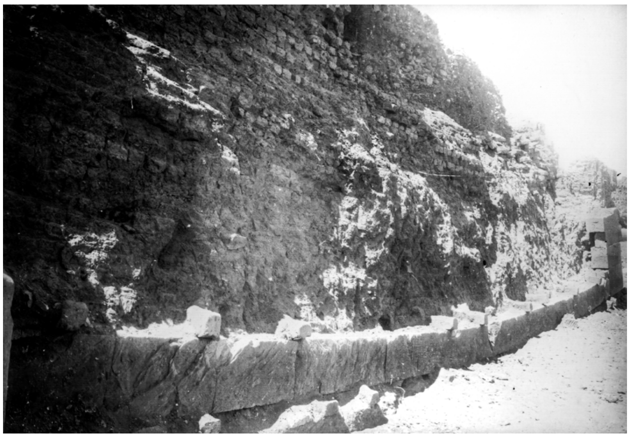

Figure 11: Archival picture of the main entrance of Dendara (end of the first half of the 20th century).
© CFEETK, fond Chevrier, picture 94582

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[24] Golvin *et al.* 1990, p. 905-946, pl. IV.

[25] This element is noted in Spencer 1979, p. 78.

[26] Some are listed in Spencer 1979, p. 116 for the enclosure walls.

[27] See Hadji-Minaglou 2007, p. 203, photo 4 (the stone reinforcement of the precinct is visible in the background, about 5 cm from the upper right corner of the picture). Many examples of corner reinforcement in civil architecture can also be observed in Tebtynis. See for instance Hadji-Minaglou 2007, p. 20, photos 17 and 18.

[28] I would like to thank J. Hourdin, archivist at the CFEETK, for having brought the existence of these photos to my attention.

The exact function of these elements is enigmatic. They are reminiscent of the reinforcing wooden elements visible on other sites, and could be the petrification of an otherwise structural detail for aesthetic or symbolic purposes[29]. This interpretation could be extended to the angle reinforcement: while there is no doubt about the protective effect of the stone facing, the spur could be a decorative element inspired by the wooden corner reinforcements seen on other enclosure walls[30].

A structural explanation can also be suggested. The archival pictures reveal the presence of other stone elements identical to the ones visible today, apparently forming a second row just below the reinforcing stone slabs (Fig. 11). Together with the first row, they might have played a role in fixing the slabs to the mud brick masonry.

The study of the construction methods was one of the main objectives of the season, but it was not the only result. Excavations carried out to establish the original boundaries of the monument led to the discovery of spaces built into the masonry.

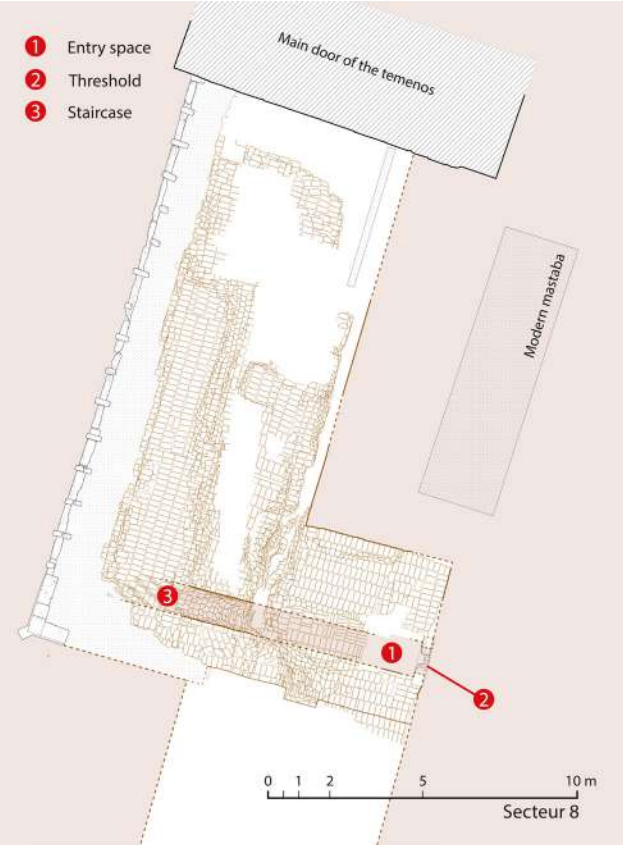

Figure 12: Plan of the newly discovered spaces of the enclosure wall.
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3. UNPUBLISHED INTERNAL SPACES

Although they were badly damaged, these new spaces may be interpreted as an entrance area associated with a staircase providing access to a higher level of the enclosure wall, which has now disappeared[31] (Fig. 12).

3.1 THE ENTRANCE AREA (Fig. 12 feature 1)

The preserved part of the entrance opens onto the interior of the precinct through a doorway at the south-west side of the main door. Its position is marked by a sandstone threshold 0.37 m wide and 1.61 m long (Fig. 12 feature 2, Fig. 13).

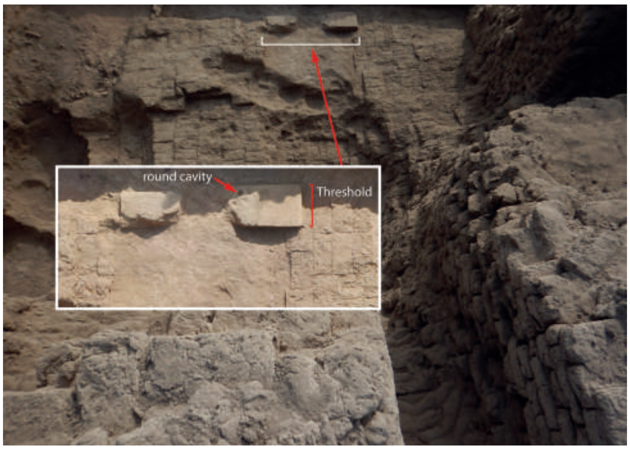

Figure 13: Threshold of the staircase.
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This formed a 6 cm high step that was worn in the middle, as a result of intensive use over a long period. The structure of the doorway is lost, but the threshold surface shows the negative of the jambs. Incised lines could indicate the position of a lost stone doorframe. They allow the width of the doorway to be reconstructed as 0.81 m – its original height remains unknown. A circular depression on the west side of the block could indicate the presence of a door, but its position, against the frame, points to a secondary rearrangement of the feature. A space 1.25 m wide and 1.14 m long was accessed through this doorway. It was floored with pure clay *mouna*. Although the side walls are only partially preserved, their position could be reconstructed thanks to the layout of the bricks in the masonry. To the north, a large pit has obliterated the plan of the entrance area and its junction with the staircase.

3.2 THE STAIRCASE

The remains of the staircase were visible before the beginning of the cleaning work. It was present in the masonry of the wall over a length of 2.50 m, about 2 m from the ground, disconnected from it. The discovery of the entrance area and careful observation of the layout of the walls allowed them to be understood accurately.

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[29] This idea is defended for other elements of Egyptian architecture in Zignani 2011, p. 15.

[30] As observed by the author at Tebtynis.

[31] Although most of the preserved enclosure walls from this period have lost their upper sections, there is a "chemin de ronde" running along the top of the surrounding wall at Deir el-Medina (see for example Baraize 1914, Figs. 14 & 15). This conception may also have existed at Dendara.

At this point, the enclosure wall is much degraded, but features two parallel alignments of bricks that stand out from the rest of the masonry (Fig. 3 feature 4). The side walls of this "trench" alternate courses of headers and stretchers, as is usually the case for the facings. The presence of these walls has led to occasional exceptions to the regular layout of the masonry core to the west of the staircase: here, the bricks are laid in a herringbone pattern. This may be for the sake of constructive efficiency: the section of wall here is too narrow to accommodate a full brick, and the herringbone pattern avoids the need for cut-outs. These details clearly indicate the presence of a 0.93 cm-wide "corridor" built into the masonry.

The side walls of this space each receive an alignment of regularly spaced cavities facing each other (Fig. 14). These cavities are almost systematically framed by complete bricks, so they were not dug afterwards and are part of the original layout. They were probably used to embed pieces of wood working as a stair nosing (the projecting edge of the tread), as is the case with the staircases at Karanis[32].

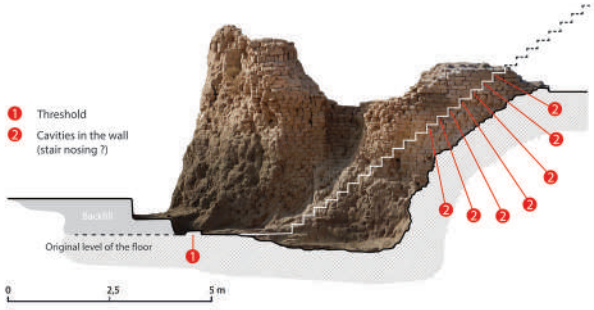
❶ Threshold
❷ Cavities in the wall (stair nosing ?)
Backfill
Original level of the floor
1
2
0
2,5
5 m

Figure 14: Reconstitution of the staircase.
© Mission archéologique de l'Ifao à Dendara, M. Vanpeene

The steps themselves have disappeared. They were made of either mud bricks – a material usually associated with wooden stair nosings – or stone. The circulation surface must have been horizontal, whereas the masonry is built with curved courses. It is therefore almost certain that the steps were constructively separated from the rest of the structure. If this alignment of cavities did indeed mark the position of the steps, they would be two bricks high (around 20 cm) and between 25 and 30 cm deep (slightly less than the length of a brick). The restored staircase would then meet the floor of the entrance area at 1.90 m from the entrance.

The presence of a staircase in the enclosure wall of late temples had never been documented before. However, there have been other instances of spaces built in these structures. This is the case at Soknopaiou Nesos, where long corridors have been noted in the walls of the *precinct*[33]. Unpublished parallels were also observed at Tebtynis[34] and Plinthine[35]. In each of these cases, a linear space similar to a corridor developed in a section of the wall, without it being possible to define its use.

4. ANOTHER BRICK IN THE WALL

The general principle behind the construction of curved-course walls is well known, and a number of syntheses have been drawn up since J.C. Golvin and his team's work at Karnak. While the mathematical and physical properties have been studied, there is still much to be learned from the technical aspects of these structures. Conserving correctly these monuments, widespread in the Nile valley, depends understanding the construction techniques used to build them.

Observation relating to the internal structure of the walls of Dendara has already produced a harvest of information. Some elements are well known, such as stone or wooden reinforcement systems. Others are new, such as the utilisation of bricks laid on edge to correct construction speed differentials between core and facing of the walls. The discovery of the staircase represents a significant advance in the understanding of the use of these structures. So far, the upper parts of these walls have only been observed at Deir el-Medina[36], and the problem of how these were accessed has never been addressed. The new data from Dendara may help to clarify how this worked.

Many questions remain. How were the curvatures of the foundations put in place and controlled? If it appears normal to observe different construction techniques in walls belonging to distant sites, observing them in a single monument could point to several phases, multiple construction teams or a very long process evolving as the work progresses. What could the remains of the walls of Dendara tell us about the story of the site? How was the work organised, how long did it continue? In an attempt to answer these questions, the ongoing work will continue to add its brick to the research on enclosure walls of the Graeco-Roman period each season.

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[32] Husselman 1979.

[33] To my knowledge, there is no detailed description of these areas, but they do appear on the site plans. See Capasso Davoli 2012.

[34] Excavations carried out on the enclosure wall protecting the temple of Tebtynis revealed the presence of a corridor built into the masonry. I would like to thank the director of the mission, C. Gallazzi, and the leading archaeologist, G. Hadji-Minaglou, for providing access to this still unpublished information.

[35] The beginning of an elongated space in the stone base of the Plinthine kom enclosure wall was documented during the 2016 season. I would like to thank B. Redon, director of the mission, and S. Dehnin, then in charge of excavations, for that information.

[36] Baraize 1914, figs. 14 & 15.

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MUD-BRICK STRUCTURES AT ABUSIR CENTRE. TRADITION, STRATEGIES, USAGE

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SUMMARY

Abusir is firmly associated with the development of Egyptian society during the Fifth and Sixth Dynasties. Alongside the completed pyramid complexes of Sahure and Niuserre, it allows an in-depth study of situations in which mud bricks (adobes) were used instead of stone in the royal mortuary architecture. The royal administration decisions occurred after the (untimely?) deaths of Neferirkare[1] and Raneferef[2] at a time when their pyramid complexes were not completed. This led to non-standard solutions concerning both the structural and architectural aspects of their monuments, including the decoration of their mortuary temples, by using "cheaper" solutions. These included the utilization of the smallest possible means – mud bricks, wood, and other materials – and changed ground plans to enable these monuments to serve cultic purposes. The best example to study these strategies is the mortuary temple of King Raneferef.

INTRODUCTION

Abusir Centre (Fig. 1) comprises royal pyramid complexes, pyramids of queens and mastabas of minor members of the royal family, and of the elite of the Fifth Dynasty (ca 2494–2345 B.C.). The archaeological evidence of building activities at the site proves that the broader Abusir area was considered in the Predynastic and Early Dynastic Period a suitable place for construction of mud brick mastabas[3]. The Userkaf sun temple[4], whose construction was apparently decisive for the establishment of the royal necropolis at Abusir, was built also in mud bricks, especially in its early construction phases (Fig.1). This fact is connected with the temple being finished after the king's death. Nevertheless, we also encounter an extensive use of mud bricks in terraces below Niuserre's sun temple in Abu Gurab (Bissing et al. 1905). Altogether four kings were buried in Abusir. Only two of them – Sahure[5] and Niuserre[6] – succeeded in finishing their pyramid complexes in stone. The mortuary temples of Neferirkare and Raneferef were finished in adobes following changed plans.

Queen Khentkaus II was the principial wife of Neferirkare[7] and mother of Raneferef and Niuserre. After Neferirkare's premature death the reign of their older son Raneferef started, which did not exceed three years[8]. The premature death of Neferirkare also influenced the building history of the queen's complex, which was finished in mud bricks, mainly during the reigns of Raneferef and Niuserre[9]. Niuserre was the last ruler

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[1] Borchardt 1909

[2] Verner *et al.* 2006

[3] Radwan 2000 ; Radwan 2003

[4] Ricke 1965

[5] Borchardt 1910

[6] Borchardt 1907

[7] Verner 1995, p. 170

[8] Verner 1995, Pl. 32, fig. 82; Verner, in Verner *et al.* 2006, p. 23

[9] Verner in Verner *et al.* 1995, pp. 38–42

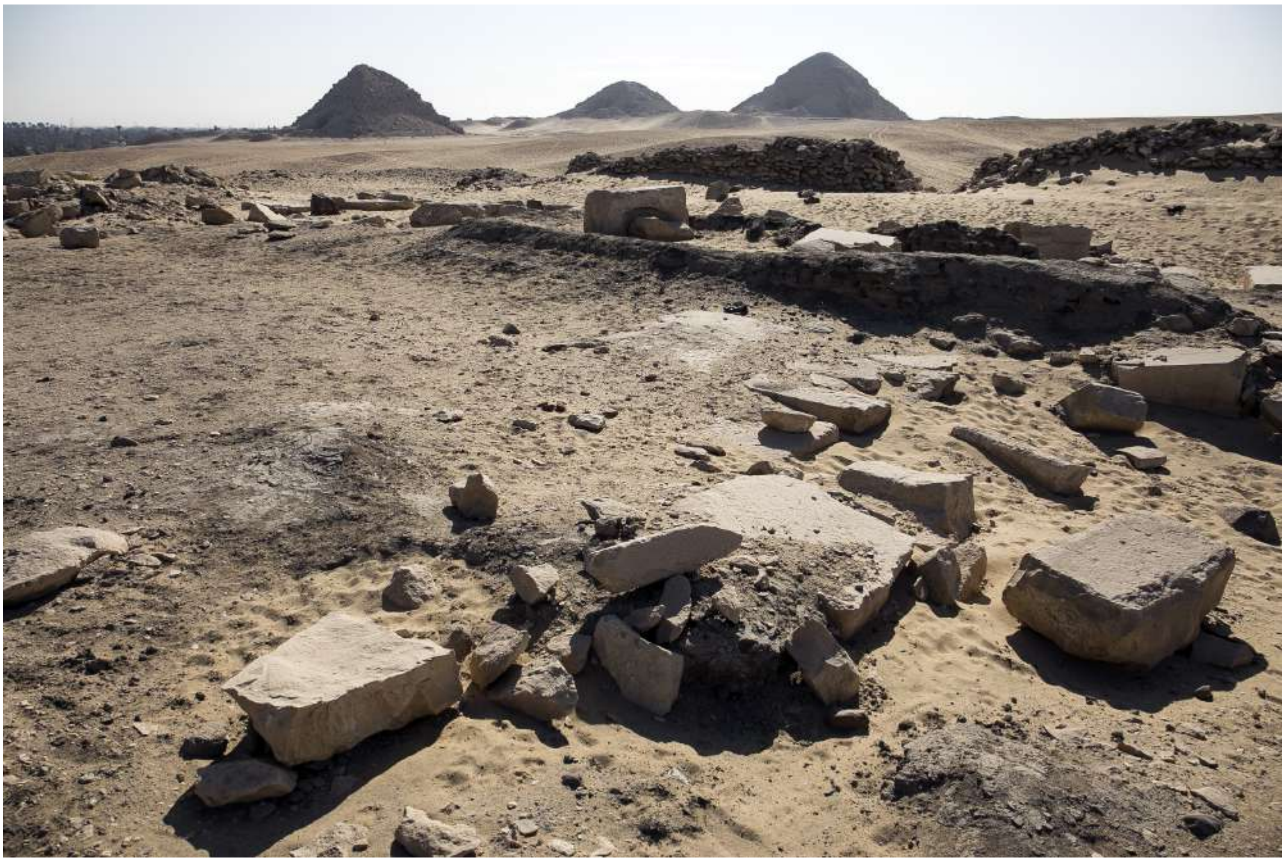

Figure 1: The sun temple of Userkaf - in the foreground a part of its mud brick masonry, in the background the royal necropolis at Abusir Centre.

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who was buried in Abusir. His ca 30-year reign[10] was fulfilled by a large-scale building plan for the Abusir royal necropolis – besides construction of his own pyramid complex (and his sun temple in Abu Gurab), he finished the construction of the mortuary complexes of his two predecessors and of his mother. Tombs of other members of the royal family were also incorporated into this area. It is thus understandable that it was necessary to cut costs when completing the monumental complexes of his brothers, hence the extensive use of adobes in their complexes.

1. DEVELOPMENT OF RANEFEREF'S MORTUARY COMPLEX

Raneferef began construction of his pyramid complex, "Divine is Raneferef's power" relatively far (700 m) from the present-day edge of the Nile floodplain; it might have thus also influenced the later making of adobes used in his mortuary temple. In line with the emerging standardisation of the royal pyramid's size, the dimensions of the planned pyramid were to be similar to the pyramid of Niuserre, but Raneferef's untimely death caused this original project to never be completed. It was adapted in haste to organize the king's funeral and burial of the king's mummified corpse, and to be able to start the functioning of his mortuary cult. The original plan of the pyramid is evidenced by a limestone foundation platform, on which a pyramid was built being changed afterwards into a "square mastaba". This unfinished pyramid had shorter sides than planned (65.5 m versus 78.5 m) and the limestone platform thus exceeded by 6.5 m the sides of the unfinished pyramid[11]. In its eastern part, the platform was also used for construction of the first building stage as well as, partially, second mud-brick stage of a mortuary temple.

To start the mortuary cult for the deceased king, a cultic place had to be prepared quickly: a small limestone sanctuary – the Intimate Temple[12] containing an offering chapel with two pillars and a magazine was built against the eastern wall of the pyramid. As it was not sufficient for a full cult operation, the mortuary temple was thus significantly enlarged – to the north, east and south – in several stages using adobes (Fig. 2).

The Early Temple[13] – built during the early phase of Niuserre's reign – included *circa* thirty storerooms, corridors, and a hypostyle hall whose ceiling was supported by twenty wooden

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[10] von Beckerath 1997, p. 155: 31 years

[11] Verner in Verner *et al.* 2006, pp. 5–25; Krejčí 2010, p. 136

[12] Verner in Verner *et al.* 2006, 44–49

[13] Verner in Verner *et al.* 2006, pp. 29–66

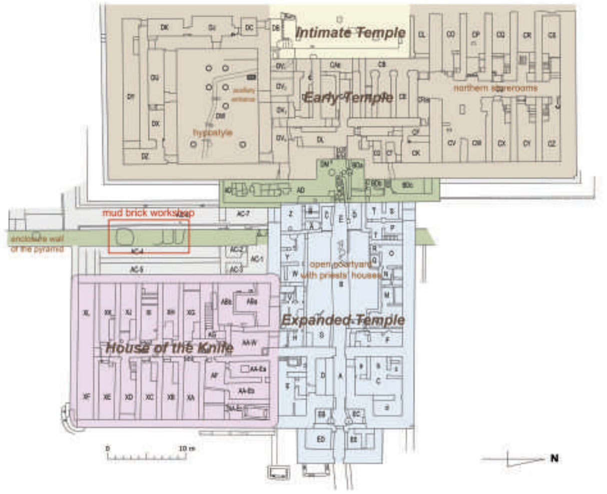

Figure 2: Plan of Raneferef's mortuary temple with indicated construction stages.

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six-stemmed lotus columns. To the north of the main axis of the temple lay a group of magazines in which the fragments of the Raneferef temple papyrus archive were found. The entrance to the temple was through a portico with a pair of four-stemmed limestone columns. The mud brick outer wall had an inclined façade.

There is a possibility that the Early Temple and Intimate Temple were planned as one building stage. This hypothesis has been supported by the northern outer wall of the Intimate Temple being left undressed[14], as if an extension to the temple had been an intention. However, the outer wall of the Intimate Temple was slightly inclined, which implies that this wall was to become the northern façade of the temple and it thus speaks against this hypothesis.

A separate construction represented a ritual slaughterhouse, the "House of the Knife"[15], built to the southeast of the Early Temple. The slaughterhouse was a north-south oriented building, one of its special features being its rounded corners. In its north-western part, animals were butchered in a small courtyard, the meat of which was used in the king's mortuary cult; in the southern part, there were storerooms.

The next building phase, dated also to Niuserre's reign, the Extended Temple, represented construction of a courtyard with 22 wooden cylindrical wooden columns supporting its ambulatory. During this stage the slaughterhouse was also incorporated into the mortuary temple[16] and this extension thus represents another turning point in the temple's development. A new columned entrance with two limestone six-stemmed papyrus columns as well as rooms between the slaughterhouse and the enclosure wall were constructed of adobes, too.

A brief overview of the construction development of the temple shows how its architects had to adapt to the king's untimely death. Along with the use of adobes, which made the construction of the temple faster and cheaper, they had to avoid incorporating a valley temple and a causeway into the king's complex. In this context, its decorative programme was completely transformed, too. Archaeological excavation showed that the walls of the temple were not decorated with scenes as would be the case of a standard stone temple, "only" with bands of colour and areas of rather small scale. This was obviously related to the fact that it was largely built of adobes. The most important motifs were transferred to faience and frit inlays, which decorated wooden naoi and boxes used for storage of temple equipment and statues[17]. Important is also the omission of the chapel with five niches[18], which at the time of construction was a fixed part of the royal mortuary temple plan.

2. MUD BRICK MASONRY OF THE RANEFEREF MORTUARY TEMPLE

2.1 FOUNDATIONS

Mud brick foundations were accessible only in Rooms DH and CS of the Early Temple[19]. It seems that for these adobes of smaller formats were used than was the case of the above-ground masonry. The brick bonding was not uniform: in the first room, layers of headers and edgers alternated with thick layers of mortar for levelling purposes; in the second room. one could see two layers of headers interchanged with a layer of stretchers and then with another two layers of headers. The foundations were not particularly deep, reaching a maximum of 50 cm. The material used for the fabrication of the mud bricks in the foundations was very similar if not the same – i.e. dark- or brown clay material with limestone chips, gravel and chaff[20].

2.2 THE EARLY TEMPLE

This temple part evidences a rather large variety of the used formats (Fig.3). In its outer walls, one can document not only that but also differences in materials from which the bricks were made. On the other hand, two brick formats (0.30–0.34×0.16×0.09–0.11 and 0.36–0.38×0.145-0.165×0.115–0.125 m), used for the construction of the north outer wall, were both made of the same material (greyish-brown mud material and a small amount of weathered pottery sherds, gravel and limestone chips). As was standard for the broad walls not only in Raneferef's temple, the brick bonding of the outer wall (A3) was also not regular on its interior. As the outer wall had to be built thoroughly, levelling layers of edgers were used in the wall.The entrance and central part of the Early Temple played an essential communication role in the framework of the entire mortuary temple. The mud-brick masonry of its rooms was worn out by intensive temple operations connected with Raneferef's mortuary cult. This initiated their rather frequent restoration and modifications. Therefore, the ground plan of this temple part is rather complicated and includes many additional walls, bricking ups, etc. This situation makes the study of earthen masonry and construction joins rather difficult. Typical for this part of the temple is the frequent use of levelling layers – in most cases consisting of edgers and thick mortar layers. On the other hand, the faces of the storeroom partitions show only basic brick bonding – A3 or A2.

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[14] Verner in Verner *et al.* 2006, p. 49

[15] Verner in Verner *et al.* 2006, p. 88–98

[16] Verner in Verner *et al.* 2006, pp. 67–82

[17] Landgráfová 2006, pp. 49–52

[18] Verner in Verner *et al.*, 2006, pp. 145–146

[19] Krejčí in Verner *et al.* 2006, pp. 129–130, Figs. 1.6.14–1.6.15

[20] Krejčí in Verner *et al.* 2006, Tab. 1.6.11

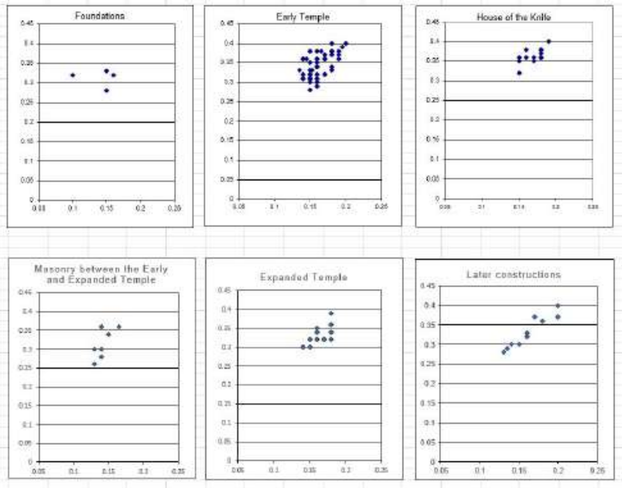

Figure 3: Formats of mud bricks used in individual building stages of the temple as well as in foundations.

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In the case of the masonry of the hypostyle hall (Fig. 4), bricks of similar dimensions but made of rather different materials were used in its individual side walls. Does this prove the progress of the work, or adobes used here were made by two brickmakers using the same mould format or is it just a coincidence? More proof of these technological procedures is apparently documented by a bricked-up entrance located in the axis of the northern wall of the hypostyle. This aperture had not been made by the dismantling of this part of the wall; it was left when the wall was being erected. It is highly probable that this aperture was used during the construction of the columned hall for transportation of needed building materials – bricks, wooden columns or beams for the ceiling construction, etc., to the hall and other rooms. After the end of its use, the auxiliary entrance was bricked up with mud bricks of two formats (0.31–0.32×0.15–0.17×0.10–0.12 and ?×0.19×0.12 m). These brick formats did not depart very much from the brick formats used in the walls of the southern part of the Early Temple. This means that the entranceway was bricked up already during the construction of other parts of this temple sector.

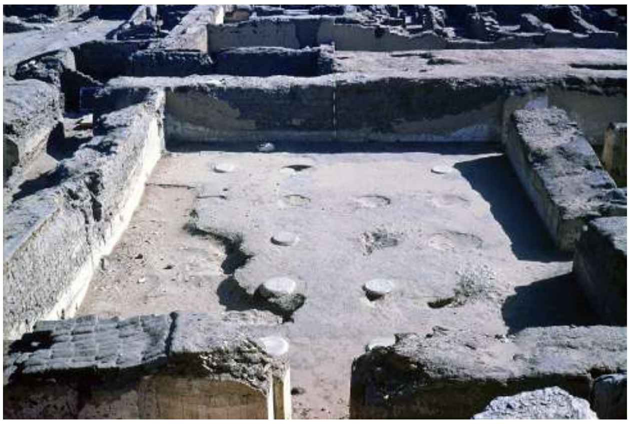

Figure 4: Hypostyle hall from the north.

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2.3 HOUSE OF THE KNIFE

The outer mud brick wall of the north-south oriented ritual slaughterhouse (Fig. 5) was constructed of three very similar brick formats. While the west, north, and east wings of the wall were constructed using A2 (2.5) bonding, the south wing was constructed with irregular bonding, with A17 bonding appearing in its eastern part. The brick bonding of its rounded corners is uneven and difficult to describe. Larger gaps on the outer face of the walls (up to 5 cm) were filled up with mortar; the brick sizes themselves are also not the same, some of them are of larger formats than others, having widths of up to 0.20 m – up to 0.35–0.40×0.18–0.20×0.115—0.12 m (and were thus the largest of the mud bricks used in the whole temple; the bricks were made of clay dark brown material, with addition of straw, limestone dust and weathered shards). The west and east group of storerooms within the slaughterhouse were built by using two slightly different formats of bricks made of the same material.

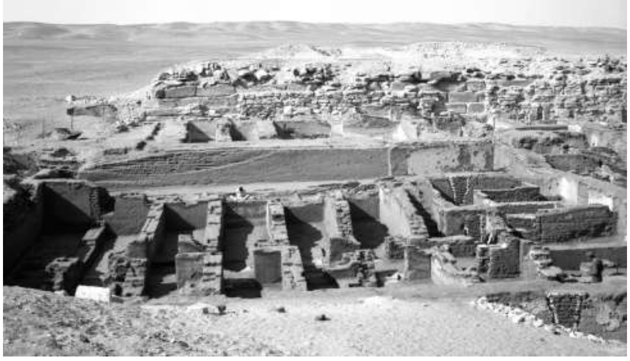

Figure 5: Ritual slaughterhouse from the east.

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2.4 CONSTRUCTIONS BETWEEN THE EARLY AND EXPANDED TEMPLE

It is very probable that Rooms AD and BDc, located in front of the entrance to the already-built Early Temple, were constructed during the following building stage. The usage of different formats and materials for their construction suppose that they were built by two gangs of workers, or in two slightly different intervals of time. It is also apparent that the outer wall of this part of the mortuary temple might have shown some problems with its stability, so there was a need to strengthen it through an additional "jacket" wall built in front of it. Room AD was cased and paved with limestone blocks.

At another time, a mud brick enclosure wall around the pyramid court was built. This wall was built of light-brown and yellow-brown "desert" bricks of rather small dimensions (0.26–0.28 × 0.13–0.14 × 0.07–0.08 m) made of material with a high admixture of *tafla*. This is an indicator of haste in the mud bricks' fabrication; this wall might not have been part of the original plan. There is thus a question of whether the bricks might not have been fabricated close to the construction site. The corners were reinforced with limestone blocks[21].

2.5 THE EXPANDED TEMPLE

In the southern wall connecting the Early Temple and the north-west corner of the slaughterhouse, as well as in the northern wall of the columned courtyard, mud bricks of similar formats and material were used[22]. Contrary to that, in the south-east corner of the temple, bricks of quite larger dimensions were used (0.36–0.39×0.17–0.18×0.10–0.11 contrary to 0.32–0.35×0.16–0.18×0.09–0.10 m built in other parts of this stage). Interestingly, no strict, visible line indicating this change in brick format was discernible in the masonry. The same can be said about the material from which bricks were made – it was similar: dark-grey clay with limestone chips and pottery shards. Does it mean the work gangs that constructed this part of the temple were not cooperating with one mould and brick-maker but with more of them? Moreover, in the southeast corner of the construction, at the junction with the slaughterhouse, another brick format appears. The bonding in this part of the masonry is not regular.

During this stage, spaces filling the area between the western wall of the slaughterhouse and the pyramid's courtyard enclosure wall were also built. Even though the dimensions of the bricks (0.32–0.34×0.16×0.08–0.09 m) used in their masonry were similar to those used in the northern or southern wall of the columned courtyard, the material from which they were made was slightly different: clay light-brown and ochre material with addition of limestone dust, chips, small pebbles and weathered pottery shards.

2.6 STAIRCASES

Inside the individual rooms of Raneferef's mortuary temple, internal constructions were also built: the most significant of these were stairways in the northern magazines of the Early Temple (as well as the staircases in the House of the Knife) giving access to their second floors. The massive stairway blocks were in all cases located just beside the storeroom entrances. The blocks for the staircases and the steps themselves were built using mud bricks of the same dimensions as those in the partitions between the individual storerooms. Their material was also the same. Mud bricks for the construction of the major staircase in the House of the Knife connected with the central corridor of the building are the same as those used in the western half of the storerooms, i.e., in the part of the slaughterhouse in which the staircase was positioned. In the case of adobes for the construction of a staircase in room T^2 their format is similar: 0.37×0.17×0.085 m contrary to 0.30–0.36×0.15–0-17×0.08–0.10 m as well as the material.

2.7 LATER CONSTRUCTIONS

The construction of mud bricks is faster and less economically demanding than stone construction, but it has its negative aspects as it is more susceptible to damage – in the case of the Raneferef temple, they developed in connection with the cult operations and weathering. Moreover, changes in the use of some spaces led to structural changes, which were able to be made in the case of brick buildings in a simpler way than the case of stone constructions. With this approach, we can detect, probably during the reign of King Djedkare[23], further development of the mortuary temple. Among them, the most visible certainly was the addition of adobe houses (for priests) built in the open columned courtyard of the Expanded Temple, which was thus diminished by half; a central path paved with limestone blocks marking the major direction of passage through this area from the temple entrance to the west to the offering hall also appeared (Fig. 6). These additions to the original masonry are in their majority easily traceable by two factors: different brick formats (0.30×0.15×0.08–0.36×0.17×0.10 m and 0.37–0.38×0.17–0.18×0.085–0.12 m) and the (brighter) material from which they were made. One of these changes was the addition of two rooms in front of the entrance to the Expanded Temple which they were flanking.

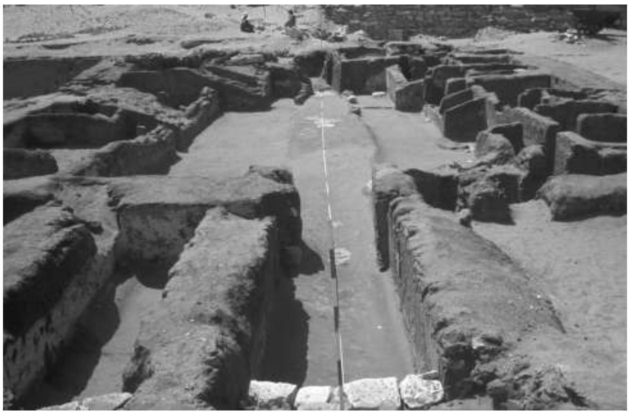

Figure 6: Columned courtyard with parasite priests' houses.
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[21] Krejčí in Verner *et al.* 2006, pp. 124–125, Fig. 1.6.11

[22] Krejčí in Verner *et al.* 2006, pp. 124–125, Fig. 1.6.11

[23] Verner in Verner *et al.* 2006, pp. 107–108

The houses of the priests' settlement were built in the courtyard ambulatory in two successive stages[24]. The first stage of these parasite houses filled the north-west, north-east, and south-west corners of the courtyard with rooms F, P, S, T1, T2, O, N, A, B, Z. The second phase of the settlement included rooms H, I, W, Y, J, K, M.

These two phases were also discernible by their brick formats. Unfortunately, it is not possible to determine precisely whether the houses were built during Djedkare's reign or later. During the everyday use of the houses, the necessity of further alternations arose – especially new partitions of the rooms were built. Both the construction joins and the use of different formats of bricks in the partitions and wall reinforcements prove that they were built later.

The destruction of the southern part of the enclosure wall of the pyramid court and the addition of another jacket wall onto the secondary outer wall of the Early temple was another larger construction change showing the effects of the probably not very stable foundation as well as effects of weather and intensive use of a walkway along it. The mud bricks of this wall were made of material apparently obtained from the enclosure wall and it had a typical composition with a high addition of limestone splinters, *tafla*, sand, weathered pottery sherds, and ashes. On the faces of this addition, bonding A3(2) appears, but the layers built with A3 bonding are, in this instance, interchanged with layers of stretchers.

2.8 MATERIAL FOR MAKING MUD BRICKS

The mortuary temple did not bring only possibility to document the bonding of the mud bricks, but also it enabled taking of samples for their material analyses, in 1991[25] which brought interesting results. The analyses showed a 70 to 80 % content of quartzite sand and 10 to 30 % of silt and clay particles, in addition to quartz, calcite and albite detritus (Fig. 7; *cf.* Kemp 2009, 80–81, Fig. 3.1.). The analyses also showed details density, bulk density, and porosity. They revealed a high similarity not only between mud bricks from different parts, i.e., construction phases, but also between ancient and modern ones. One can always see an endeavour to keep the content of the clay particles as low as possible, which has always been reduced by the addition of sand and chaff. This is because these fractions prevented the swelling of the clay fraction at higher water contents and its crumbling at lower water contents and thus prevented the deterioration of the bricks.

2.9 MUD BRICK WORKSHOP

Another of important benefits of excavation in Raneferef's temple represents unearthing of a mud brick shop. It was created on the lowermost preserved part of the above-mentioned dismantled enclosure wall, and represented by series of four depressions. Because of their form, they can be interpreted as a place where the mixture for making adobes was prepared[26]. The depressions were used for remixing the material consisting of dismantled temple brickwork with additives[27] which was then used for the fabrication of new mud bricks. The bottoms of the depressions were formed by crusts. It is questionable whether these crusts were created intentionally by the workers for static reasons to support the dough against the ground, or whether these crusts were formed by themselves during the mixing and drying of the brick dough.The southernmost and the best-preserved depression had an almost circular ground plan, a width of 2.40 m and a depth of 0.10–0.15 m (Fig. 8).

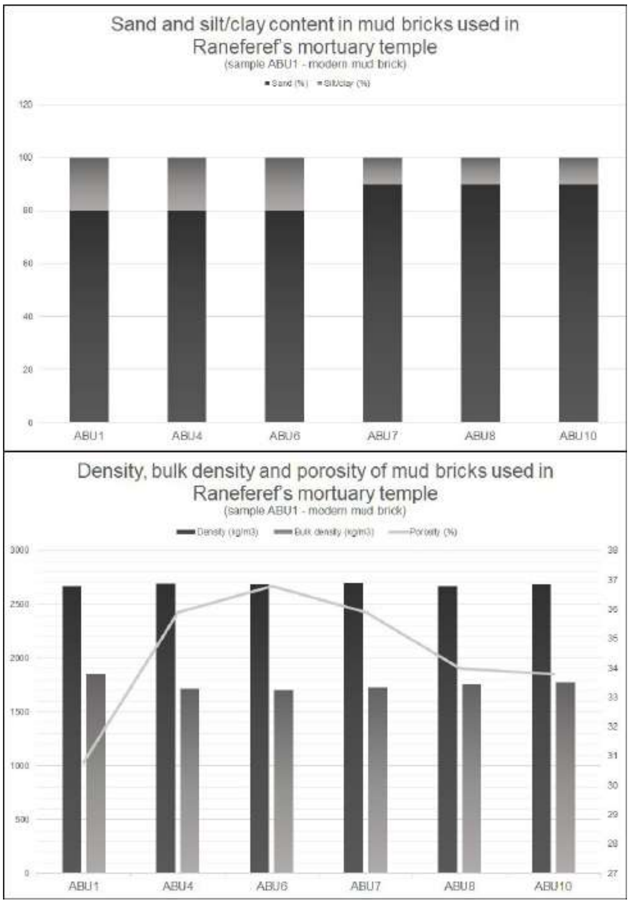

Figure 7: Material and physical aspects of mud bricks used in Raneferef's mortuary temple following results published by Vaněček (1993).

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This depression probably developed in two phases shown by two crusts (0.05–0.07 m high) consisting of Nile mud mixed with sand, limestone, sherds and broken bones. Similar depressions were unearthed in el-Asasif and they were used for mixing mortar[28].The possibilities of how to connect the functioning of this workshop with the specific building phase of the temple's development are limited. As has been established with the destructed enclosure wall of the pyramid courtyard, it is clear that it was created after this wall was demolished. It thus seems that the workshop functioned towards the end of the temple development. One can also hypothesize that the material obtained from the crushed mud bricks of the deconstructed enclosure wall was used for remixing the brick dough in this workshop and afterward for the fabrication of bricks of reinforcing masonry along the outer wall of the Early Temple.

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[24] Krejčí in Verner *et al.* 2006, pp. 126–128

[25] Vaněček 1993

[26] Krejčí 1995

[27] for this process, see: Chevrier 1964, pp. 12–13; Eigner, 1984, pp. 104–105, Photo 30

[28] according to Arnold and Settgast 1966, Abb.1, Taf. XIIIa; for modern analogies, see: Fathy, 1969, pp. 286–293.

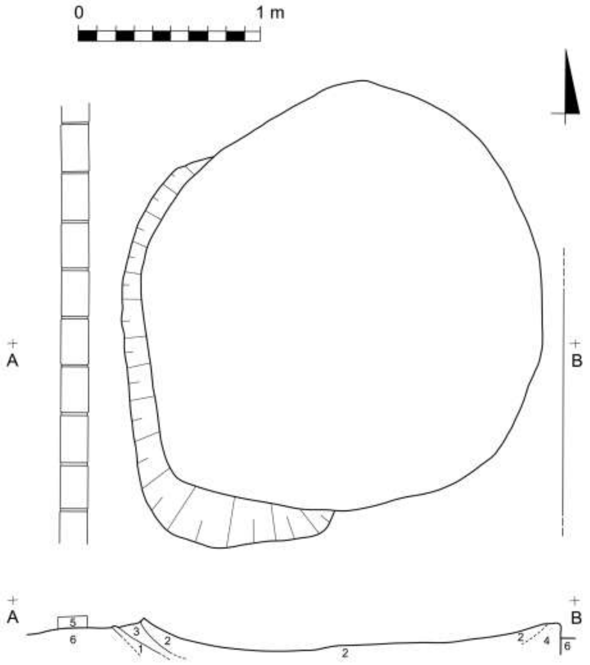

Figure 8: Mud brick workshop, plan and section (1-The first phase of the crust; 2-The second phase of the crust; 3-Sand fill with charcoals and pottery sherds; 4-Intact part of the enclosure wall of the pyramid courtyard; 5-Mud bricks; 6-Mud floor).

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3. OLD-KINGDOM ANALOGIES TO THE DEVELOPMENT OF THE MORTUARY TEMPLE OF RANEFEREF

Raneferef's mortuary temple belongs to a group of mortuary temples in which adobes were chosen as a solution for the situation when it was necessary to ensure the burial and operation of the mortuary cult of an untimely deceased king. It seems that the earliest attestation of this practice is Radjedef's pyramid complex in Abu Rawash. To the east of the king's pyramid, remains of the mortuary temple were unearthed[29]. As is the case of Raneferef's, its limestone part also had rather small dimensions which show that it was built in haste. To the east and south of it, two cultic mud-brick installations and further to the east and northeast other, more profane parts were built, all of adobes.

Another example is the pyramid complex of Menkaure in Giza[30]. After Menkaure's death, his mortuary temple was finished, probably by Shepseskaf, in adobes added to the already-built limestone core masonry. The architectural forms – especially panelling – which were used in this stage, were also used in Shepseskaf's own tomb complex in Saqqara South[31]. It is apparent that his tomb complex was not finished before Shepseskaf's death and thus completed in adobes, too. Its older and western part, touching the mastaba, was built of limestone and contained an offering hall and magazines. Its eastern part, made of mud bricks, consisted mainly of a courtyard. A causeway, built and vaulted with adobes, led to the mortuary temple from a not-yet-discovered valley temple. In this respect, we see a difference in comparison with Menkaure's and Shepseskaf's complexes to those of Raneferef and Neferirkare, which both lack a documented construction of either a causeway or valley temple.

The closest in time and place to Raneferef's mortuary temple is that of Neferirkare (also built in several construction phases). Its oldest and westernmost part was built of limestone and consisted of an offering hall, magazines, and a chapel with five niches. Contrary to the temple of Raneferef, fragments of relief decoration were found there. Other parts of the temple were built with adobes. The layout of the mud brick part of the temple is rather different than that of Raneferef; it included a large open courtyard, magazines, a columned entrance corridor and another columned corridor which enabled access to the pyramid courtyard. Parasitic adobe dwellings were unearthed in the temple, too. As in Raneferef's temple, this development was due to the absence of a pyramid city.

The mud brick parts of the Raneferef and Neferirkare mortuary temples were partly built at the same time, i.e., during Niuserre's reign. In Neferirkare's mortuary temple, we encounter some brick bonding and formats that are the same or close to those used in Raneferef's Early Temple. The mud bricks laid out in the enclosure wall of the Early Temple have almost the same dimensions (from 0.36×0.16–0.18×0.10-0.11–0.36×0.18(0.19)×0.11–0.12 m) as the bricks used in the construction of Neferirkare's "treasure rooms" (0.35×0.18×0.12 m[32]). Some of the 0.30×0.15×0.10 m bricks built in the eastern façade of the temple, used with A3 bonding[33], are the same as those used in the northern sector of the Early Temple and very similar to those used in the construction of the brick wall around Room AD in the entrance sector of the Early Temple. It is, therefore, possible, though not directly demonstrable, that these structures were built by the same workshop. Unfortunately, it is not feasible to fully compare these two constructions – much of the necessary data for Neferirkare's temple

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29. Valloggia 2011, pp. 53–58

30. Reisner 1931

31. Jéquier, Dowham 1928, pp. 13–21

32. Maragioglio, Rinaldi 1970, p. 134

33. Maragioglio, Rinaldi 1970, p. 154

is missing. Even in the construction of the stone part of the temple, a strategy of *provisionality* was chosen, whereby inferior limestone masonry (in terms of quality of material and workmanship) and adobes were used to complete some parts of the temple.

CONCLUSIONS

It is apparent that the original plan of Raneferef's pyramid complex, and that of the mortuary temple, was simplified, changed and reduced after the king's premature death, and only part of it was built in stone. With this development, also the analysis of the proportions between the lengths and widths of mud bricks used in the temple can be connected. In majority, it oscillates around the "ideal" value 1:2[34] and so corresponds with A.J. Spencer's dating of this ratio to the period of the Old Kingdom[35]. Within the statistics of the dimensions of the mud bricks, it is possible to document a slight deviation from this average only in the construction of the Expanded Temple (in its south-eastern part) and during later modifications. It shows an important, although transferred, role of the administration even in such detail as the format of the mud bricks. During large, well-directed extensions of the temple, this proportion is standard; during later modifications when the role of the central authorities might have been weaker, it is slightly different.

It is evident that the size and complexity of construction under time stress prompted the use of varied brick formats made by more gangs of workers and more brick-making workshops (cf. fig.3). Concerning brick mixture, it is interesting that even though one encounters more brick formats in the masonry, the material from which they were made was the same or *vice-versa*.

A different situation is with the staircases with the heterogeneous nature of the used brick bonding and formats. Structures, such as side walls, supporting walls, etc., were usually built after the erection of side walls of rooms. The material for making these bricks was sometimes different, as can be documented in the northern storerooms of the Early Temple. Light brown material with a high addition of tafla and sand, apparently prepared not far from there and typical of later brick wall restorations, was used there.

In concern with a more general focus, it is clear that after the death of the king in the Old Kingdom, the most important task was to secure his burial – this meant the eventual necessary completion of the burial chamber and also the construction of the tomb. Another task was to secure a place for the king's mortuary cult – the offering chapel and the necessary storerooms built of stone. Other spaces may already have been built of mud brick, as the pyramid temples discussed above show. This indicates that even though the royal cult and constructions were bound by religious codes, it was possible, keeping the most important premises, to adapt the layout of the sacral constructions to the changed conditions even in the case of royal pyramid complexes.

ACKNOWLEDGMENTS

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[35] Spencer 1979, Pl. 41

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THE ARCHITECTURAL DESIGN OF NEWLY DISCOVERED POTTERY AND LIME KILNS AT TABBET METAWAH SITE, WEST ALEXANDRIA

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SUMMARY

The Tabbet Metawah (تبة مطوّح) is located about 20 km southwest of Alexandria and measures 3.44 hectares. It was one of Lake Mariout's islands during the Graeco-Roman period. During a salvage excavation conducted at the northern part of the site between the 25th of December 2021 and the 31st of March 2022, four kilns were discovered, three of them at a pottery workshop located in the northwestern depression area of the site (sector 40000), while the fourth is a lime-kiln located at the eastern uppermost part of the site at a sector called 30000. This study aims to investigate in detail the architectural design of these kilns.

INTRODUCTION

During a salvage excavation conducted at the northern part of the site between the 25th of December 2021 and the 31st of March 2022, three kilns were discovered, at a pottery workshop located in the northwestern depression area of the site. Two of these kilns, of exceptional design, were built together and share the same foundation cut into the bedrock; they have been dated to the early Roman period.

The third kiln is to the south of these. It too, has a foundation carved into the bedrock, although it is smaller and of a different design. This kiln dates from the Ptolemaic period. In use through three phases, this kiln served several functions: originally for firing ceramics, then to calcine limestone, and finally to store vessels.

The fourth kiln is located at the site's northern extremity and was used for limestone calcination during the Later Roman period. It was not fully excavated and appears to have been abandoned abruptly, because some limestone cobbles remained in its firing chamber without being completely calcined.

1. KILNS OF THE POTTERY WORKSHOP

This pottery workshop measures 71 m north to south and 57.70 m east to west. Its main output comprised AE3 Amphoras and their stands. The three pottery kilns, A, B, and C, were discovered in the southern part of the workshop. Kilns A and B, of exceptional design, were built together and share a foundation cut into the bedrock; they have been dated to the early Roman period. Kiln C, which is located south of them, is smaller and of a different design (Fig. 1). They are all updraft kilns, a type of pottery kiln known from antiquity and still used today in Egypt, in which the fire is generally positioned underneath the vessels and separated from them by a perforated platform as hot gases - the draught - pass upward[1]. The Tabbet Metawah kilns were constructed using bricks of Mariout calcareous clay known as *tafla.*

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[1] Arnold, Bourriau 2000, pp.106-107.

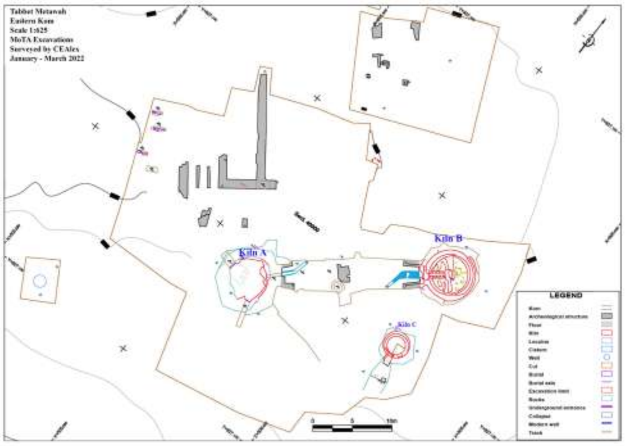

Figure 1: The plan of the pottery workshop at sector 40000 at the Tabbet Metwah Site.
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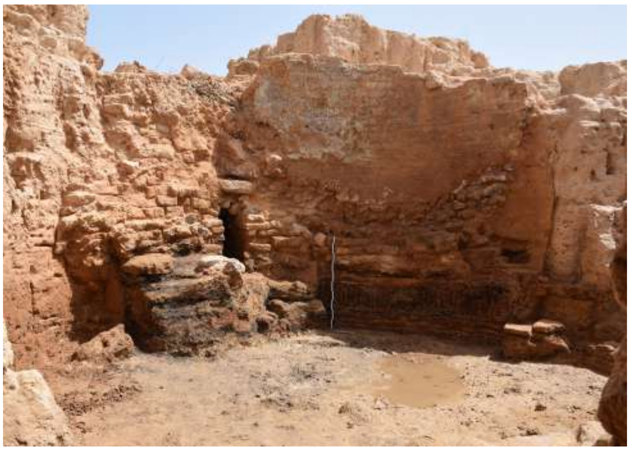

Figure 2: The remnants of kiln A. View from the west.
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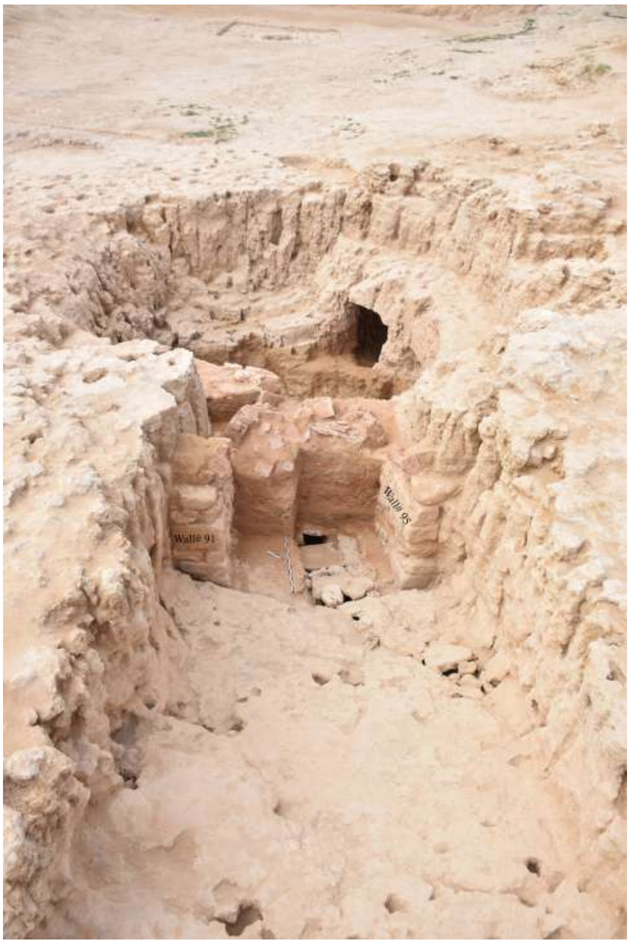

Figure 3: The tunnels of kiln A. View from the east.
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1.1 KILNS A AND B

These two kilns were constructed concurrently, utilising the same foundation-cut and design. The builders of these kilns made use of the island's topography by digging the foundations into the limestone bedrock. Their firing chambers are separated into two sections, one with a perforated *tafla*/clay platform, and the other carved into the bedrock. They were used not only for firing AE3 Amphorae but also for other vessels and possibly for calcining limestone.

There is a 33.50 m longitudinal foundation cut in the bedrock from east to west and a 3.85 m wide cut in the bedrock from north to south. The two ends of the foundation cut are circular and 7.30 m in diameter for both kilns A and B.

1.2 KILN A

Kiln A was badly destroyed, but its outline was determined by the circular foundation cut into the bedrock. Fortunately, a section of the kiln wall on eastern side (#13) was preserved (Fig. 2); and was excavated to its foundation courses, at the base of the kiln. This wall is 4.50 m in length from north to south and 0.15 m in width, with 3 m of its height is remaining, The remaining parts of the wall demonstrate how it was constructed over the bedrock. The edges of the cut in the bedrock were first refined, then padded with mud, before constructing the wall of *tafla*/clay bricks, arranged horizontally. These bricks have been significantly reddened by heat from the kiln, particularly in the foundation courses closest to the heat source. The bricks measure 25 × 25 × 8 cm and *tafla* was again used as mortar to fill the gap of approximately 0.50 cm in the vertical and horizontal joints. The arrangement of the bricks varied in different parts of the structure. The eight foundation courses, which are part of the firebox, are thicker with the four lower courses laid as stretchers and the fifth with the bricks set upright (soldier courses), followed by two more stretcher courses. *Tafla* was again used as mortar. A gypsum layer was used to line the floor of the firebox. The upper part of the wall related to the firing chamber is mud-plastered and reveals some repairs, which is common on pottery kilns owing to continued firing.

The entrance to the firing chamber of kiln A's is located on its eastern side (Fig. 3). Two limestone consolidation walls #91 and 95 support the arched entrance. Wall #91 was supported by a thick *tafla* brick wall 1.97 m long from north to south, 1m wide from east to west, and 2.50 m high; the function of this wall is unclear; it could be a repair of wall #91, as part of the arch of this wall collapsed and was covered by this *tafla* brick wall. Another suggestion is possible reuse of that consolidation wall. There is no other evidence that the region was occupied after the amphora production activity, thus the first suggestion is more plausible.

As with kiln B, these two consolidation walls were overlaid of red-bricks, which formed the vaulted roof of the tunnel leading to the entrance of the firing chamber; however, because parts of the red-brick arch are better preserved than in kiln B, it is clear that this tunnel had a vaulted ceiling (Fig. 3).

Despite the poor preservation of Kiln A, it was possible to excavate the entire tunnel. It is a curving tunnel 6.15 m long and 1m deep with a steep slope from northwest to southeast. It begins at about 0.26 m in width, where the lower part of an amphora lies *in situ,* and widens to 0.63 m in width near the stokehole, becoming semi-straight near the entrance with a fairly steep vertical slope. This tunnel was flat-roofed by limestone slabs, perhaps to make it easy for the potters to walk. Unfortunately, there is no evidence whether it was overlaid by red-brick tiles as in kiln B. Part of the tunnel was roofed by irregular limestone cobbles (Fig. 3). The entire tunnel was excavated up to the stokehole. It has a vaulted opening 0.75 m in height by 0.26 m in width that opened in the previously mentioned wall #13 of kiln A. The inner side of the stokehole is made up of *tafla* bricks that are heavily reddened in a horizontal arrangement, while the upper domed shape of the stokehole is constructed of *tafla* bricks arranged vertically and slightly inclined. Close by this aperture, is what appears to be the remains of a *tafla* brick pillar supporting the missing perforated platform.

1.2 KILN B

Kiln B is better preserved than Kiln A. It is an updraft cylindrical tower-like kiln with concave sides, that has a unique design in comparison to the other amphora kilns discovered in the Mariout region[2]. It has an inner diameter of 5.10 m and a preserved height of 2.55 m. Most of the brickwork is arranged horizontally and the *tafla*/clay bricks have been significantly reddened by heat, particularly in the lower courses; the bricks measure 25 × 25 × 8 cm, and *tafla* as mortar fills the joins of approximately 2cm between each brick's vertical and horizontal sides.

In a unique design, the firing chamber is divided into two sections by *tafla*/clay walls #100 and 122 (Fig. 4). Unfortunately, the southern wall #122 was demolished leaving only its foundation, while the northern wall #100 is well preserved, measuring 2.03 m in height, 1.80m in length from north to south, and 0.30 m in width from east to west. The joins of approximately 0.50 cm are filled with *tafla* mortar. The brickwork is arranged horizontally on the south side, but on the northern side it is difficult to determine the arrangement due to the serious deterioration of the surface. The wall slopes slightly from east to west, and abuts the limestone platform on the east side of the firing chamber. Between these two walls is an entrance 0.64 m wide.

The east side of the firing chamber exhibits an interesting design of a carved platform in the bedrock instead of a *tafla* perforated platform as expected in the usual design of pottery kilns in the Mariout region[3]. For example, the kiln located in sector 7 at the Akademia site approximately 20 km west of Tabbet Metawah is of 12.65 m exterior diameter and 7.68 m interior diameter, with a perforated firing chamber platform of *tafla* brick. [4]

This carved platform in the bedrock of Kiln B at Tabbet Metwah is riddled with irregular holes, that are more than 1m deep; unfortunately, a thorough inspection of these holes was not possible. It is worth noting that the bedrock on the entire island contains many holes in various locations, similar to those found within the kiln, therefore it is not clear whether these holes were carved deliberately or resulted from the natural erosion of the bedrock.

An inner *tafla* brick wall (#109) was built against the kiln's original wall #57 on one side of the firing chamber. This internal wall measures 4.58 m north to south, 0.26 m east to west, and 1.65 m high. The brickwork is generally arranged horizontally, with an uneven face in the lower part of the wall. *Tafla* was used as mortar to fill joins of approximately 0.30 cm between the horizontal and vertical sides of each brick.

On the western side of the firing chamber the half-circular *tafla* perforated platform that separated the fire from the vessels to be fired is considerably demolished. This platform might have been supported by the continuous ledge along the internal wall of the kiln. This ledge is constructed of brick arranged horizontally against the internal wall of the western side of the kiln. Pathway #99 through which potters walked to load the kiln is the best-preserved section of the platform. It is 2.05 m long from east to west, 0.35 m wide, and 0.63 m high. It was constructed with seven horizontal courses of *tafla* bricks, with the three lowest courses protruding from the original width of the pathway. This protrusion contains four holes on each side, 0.15 m wide and 0.22 m high (Fig. 4).

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[2] - Other amphora kilns have been discovered in the Mariout region, at Borg El-Arab, Marea, and Academia. For more information about these kilns; El-Ashmawi 1998, p.55-64., Babraj *et al.* 2012, p.1003-1014., Pichot 2022, p.33-46.

[3] Arnold, Bourriau 2000, p.109.

[4] Pichot 2022, pp.37-38.

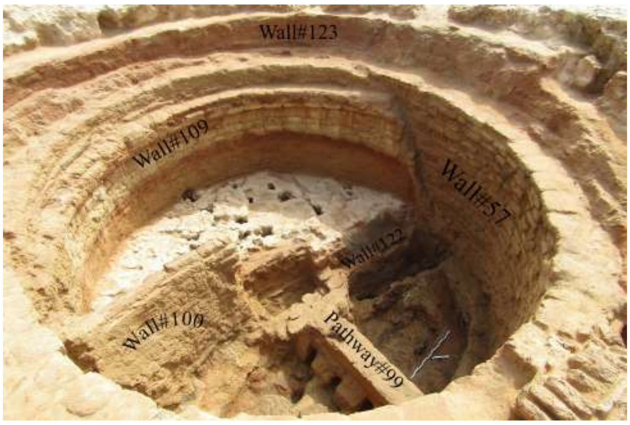

Figure 4: The firing chamber of kiln B. View from the top.
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Unlike the customary designs of ancient and contemporary Egyptian kilns, which were open-topped rather than having a roofed ceiling[5], it appears that the Tabbet Metawah kilns had a roofed ceiling, and vessels were loaded into the kiln from the side. The low wall #123 of four courses of *tafla* bricks that rests on top of the main wall #57 of the kiln may be evidence for the roofing (Fig. 4). Loading of the kiln would have taken place via the entrance in the western side of the firing chamber (Fig. 5), where potters could enter to load the kiln by moving on pathway #99. This well-preserved arched entrance is 2.20 m long from north to south, 1.90 m high, and 0.70 m thick, and is formed of red bricks each measuring approximately 25 × 25 × 5 cm, with two consolidating walls #92 and 93 made of irregular limestone blocks arranged in seven regular courses. The Northern Consolidation Wall #93 measures 2 m long from east to west, 0.75 m wide from north to south, and 1.60 m in height, while the southern wall #92 measures 2.20 m long from east to west, 0.68 m wide from north to south, and 1.71 m in height. An arch of red bricks spanned the space between the two walls to form a vaulted tunnel leading to the entrance of the firing chamber (Fig. 5).

The design of the firing chamber and its entrance is not the only thing that is remarkable about this kiln, but also the design of the firebox and its tunnel. It was difficult to complete excavation in the firebox of kiln B and its entrance for fear of collapse, only a sondage of c.1×1 m into the demolished *tafla* platform of the firing chamber was excavated, where approximately six phases of firing activity in the kiln were detected. The tunnel leading to the firebox is carved into the bedrock. It is a curving tunnel 4.50 m long with a dramatic slope from southwest to northeast. It starts very narrowly approximately 0.26 m wide where the upper part of an amphora was found, and part of the tunnel's aperture from that side was roofed with slag pieces. This tunnel widens at the stokehole, through which the kiln was fueled, with a width of about 0.67 m, and becomes straight near the stokehole, running from east to west and vertically to the vaulted entrance of the firing chamber. The tunnel in that part had a truss roof of limestone slabs to the stokehole, which is situated beneath the entrance to the firing chamber. This roof was perhaps designed in this manner to spread the load, as it was overlaid by a layer of red brick tiles. Because walking over a truss roof is difficult, these tiles may have been placed to facilitate the potters' access to the firing chamber (Fig. 5).

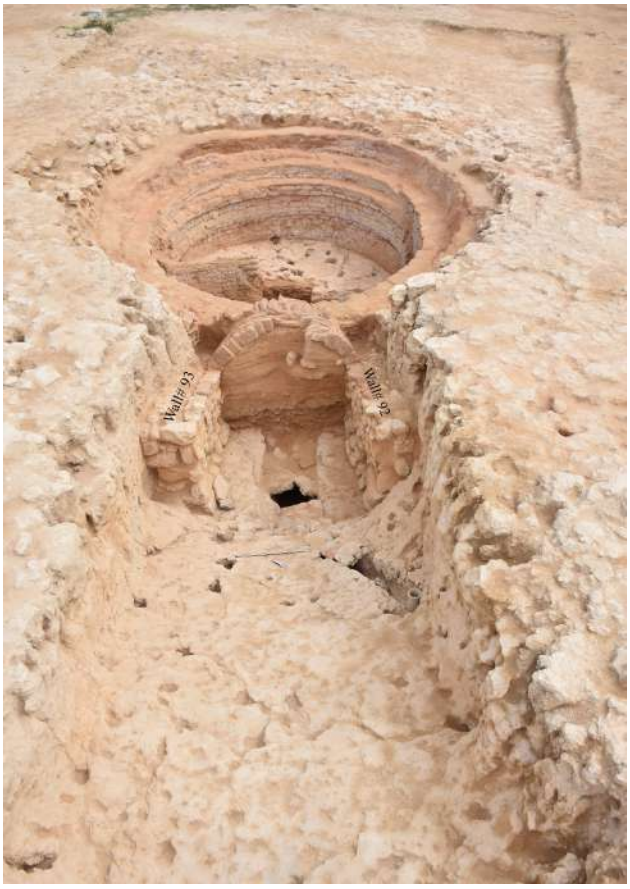

Figure 5: The entrance of kiln B and the tunnel of its firebox. View from the east.
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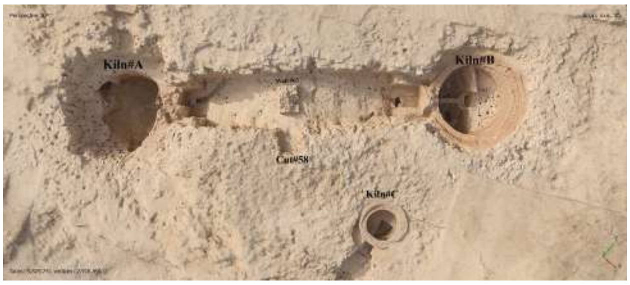

Figure 6: Top view of the tunnel between kilns A and B (extracted from the photogrammetry 3D model).
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[5] Nicholson 2009, p.6.

1.4 THE TUNNEL BETWEEN KILNS A AND B

The tunnel connecting the two kilns (Fig. 6) was dug into the bedrock as part of the foundation for the two kilns and is 18.50 m long from east to west and 3.90 m wide from north to south. It was divided into two parts by a small limestone wall (#63) 2 m long and chamfered so that it sloped steeply from east to west towards Kiln A and from west to east to Kiln B. This wall stands in front of a small semi-rectangular cut in the bedrock (#58) filled with *tafla* deposit, which served as a step for the potters to descend to the kilns, while wall #63 was also used for dividing work between the two kilns.

1.5 KILN C

Kiln C is smaller than kilns A and B, and it is located south of them. It is a circular kiln with an inner diameter of 2.35 m and a preserved height of 1.37 m that has a different design from the foregoing examples. In the plan (Fig. 1), it appears to be shaped like a horseshoe. The foundation was cut into the bedrock with a diameter of 3.57 m, and the kiln has a tunnel some 3.85 m long running from north to south.

The brickwork consisted of *tafla* bricks arranged horizontally, which have been significantly reddened by heat, especially in the lower course. The bricks measured 25 × 25 × 8 cm, and *tafla* mortar was used to fill the gap of approximately 2.50 cm in the horizontal joints, but more carelessly in the vertical ones. There are remains of mud plaster on the inner side of the wall and the floor of the kiln was lined with a gypsum layer that directly overlaid the bedrock.

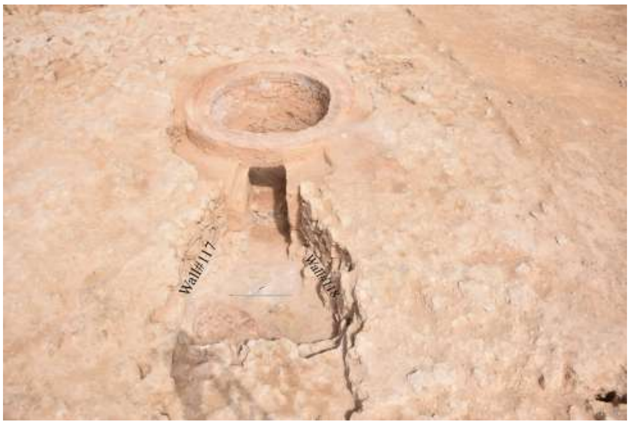

Figure 7: Kiln C. View from the south.
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This kiln has a vaulted entrance on its southern side, probably to avoid the north wind, which is 1.43 m in height and 0.73 m wide. This entrance is flanked by two limestone consolidation walls #117 and 118 that also surround the tunnel leading to the entrance. The east limestone consolidation wall #118 is 1.88 m long from north to south 0.33 m wide and 1.88 m high, while the west one #117 is 2.33 m long from north to south and 0.30 m wide and 1.70 m high. The two walls were constructed of irregular shaped limestone blocks. Because the kiln is utilised for different functions at different phases, determining whether this entrance led to the firebox or the firing chamber is challenging. Two steps were carved into the bedrock, leading to a small, sloped tunnel from south to north that led to the kiln's arched entrance (Fig. 7).

2. THE LIME KILN D

Kiln D is a late Roman Period lime kiln, located in the northern part of sector 30000. It is horseshoe shaped in plan (Fig. 8). Its outer diameter is 1.70 m, inner 1.23 m, and it has a preserved height of 0.80 m. The brickwork is of *tafla* bricks, arranged horizontally, and the bricks were reddened from heat, especially on the inner side of the kiln. The bricks measure 25 × 25 × 8 cm, and sometimes medium-sized irregular limestone cobbles were used to fill the gaps between the *tafla* bricks, with *tafla* being used as mortar.

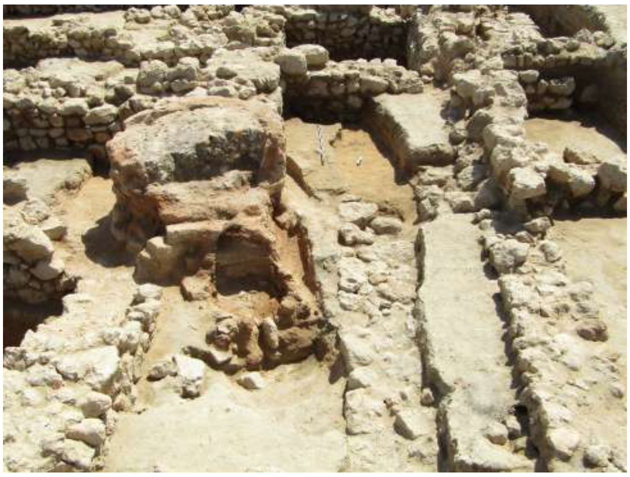

Figure 8: The lime Kiln D at sector 30000. View from the north.
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The tunnel is approximately 1m long from northwest to southeast, 0.92 m wide and 1.05 m in height, and leads to a low draw-hole to remove lime. This low draw-hole is approximately 0.65 m high by 0.52 m wide, but it was not excavated due to the possibility of collapse. A similar decision to not excavate for the same reason was made for the firing chamber.

Two low steps were carved into the *tafla* deposit on the northwestern side of the tunnel, leading to the low draw-hole. Unlike the preceding kilns, this one is not sunk into the ground and its construction has destroyed the northern portion of the Ptolemaic structural units that occupied sector 30000, while some of the Ptolemaic walls were reused to support the sides of the kiln tunnel. This kiln is of the same design as a contemporary lime kiln discovered at Taposiris Magna[6] located approximately 34 km west of the Tabbet Metwah site.

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[6] Redon *et al.* 2021, p.13.

During the medieval period, the site was used by the Bedouin for burials, and two of these burials were cut into the firing chamber of kiln D. The excavation of these burials revealed a half-section of the firing chamber, with incompletely calcined limestone cobbles within, suggesting that this kiln was abandoned before completing its operation.

It should be noted that no lime pits were found on the site during this excavation, which could be attributed to severe looting activity which has destroyed major areas of the site in recent years. Or perhaps the kiln was fed primarily by reusing the limestone cobbles used in the Ptolemaic structural units.

3. DISCUSSION OF THE DESIGN OF THE KILNS

According to the preliminary ceramic study, Kilns A and B date between the 1st and 3rd centuries A.D. The reason for their unusual design is debatable, and various hypotheses can be proposed. The first is that the firing chamber division may have been constructed to fire two different types of wares, requiring different temperatures. This hypothesis may be supported by the discovery of tableware in the higher deposits that sealed the limestone platform on the east side of kiln B, while on the west side of the firing chamber, only sherds of AE3 amphorae and their stands were found. A comprehensive ceramic investigation of these two kilns has not yet been completed and it is hoped that the picture will become clearer once this task is concluded.

The second possibility is that these kilns were used to fire two different materials: pottery on the *tafla* platform side and calcinate limestone on the limestone platform. This would require that the fire was set over the limestone platform on that side, which might explain the construction of the *tafla* brick wall that divided the firing chamber to control the temperature by reducing thermal stress. Perhaps the heat for firing the pots was supplied by two different sources: the firebox beneath the perforated *tafla* platform on one side, and the entrance by the *tafla* brick wall that separated the firing chamber on the other. The horizontal firing technique is similar to the box oven, which was not prevalent in Ancient Egypt but has its archaeological evidence at El-Amarna. The box oven is a structure with a wall surrounding the pots inside. The fire could be inside the wall or outside, drawn in through an entrance at the bottom[7].

The technique of firing pots and lime in the same kiln may have been similar to that which is still done in some pottery kilns at Badura at Dakhla Oasis, where they utilise the same kiln to produce pottery and lime, however, the design of Badura kilns differs from the Tabbet Metawah kilns. At the Badura kiln, the pots and lime are fired in the same firing chamber, where the perforated platform has a central hole covered by a small vault where the limestone is piled in a conical heap while the inside is empty, and the pots are arranged around the limestone pile[8]. Another intriguing aspect of the construction of these kilns is the firebox tunnel, which was quite long and narrow. The reason why this one-of-a-kind design was created and how it was employed is unclear. This design may have been influenced by the geological nature of the island, which is dominated by rocky terrain. The builders of these kilns had to carve their kilns into the bedrock, and they may have built this long narrow tunnel to introduce the reeds used as fuel for the kilns, and to keep the bundles needed during firing away from the strong wind.

The upper and lower parts of the *in-situ* amphorae at the beginning of the tunnels leading to the firebox of kilns A and B might be have been reused as stands for water-filled jars for the use of the potters, who were exposed to severe heat from the firebox sunk into the bedrock,[9]

Based on an ethnoarchaeological investigation of the firing temperatures of roofed and unroofed kilns, (which is perhaps more reliable than the experimental approach since it reflects traditional skills that are closer to those of ancient potters)[10] it appears that the temperature in roofed kilns ranges between 800-900°C[11]. Any interpretation requires the ability to recognize these procedures from study of the vessels. Digging the kilns into the bedrock enhanced the firing process[12]. I am optimistic that once the ceramic and archaeobotanical studies are done, we will be able to acquire satisfactory results.

Kiln C, may be the oldest in the workshop, and it contains several phases with various functions. The expected perforated *tafla* platform in the firing chamber is missing, but there is a remnant of it in the stratigraphy at the kiln's entrance, indicating that this kiln was used as a pottery kiln in its early phase. In the following phase, the kiln may have been used as a lime kiln, which would explain why the *tafla* platform was removed. The reason for this removal is that the platform used in pottery kilns was not suitable for the limestone calcination procedure, which requires either the direct firing of the limestone or another type of separation not used in pottery kilns. The region about 2.5 m to the south of the Kiln C could have been used to extinguish the lime.

The final use of this kiln was as a storage area for various pottery wares. In this phase, several pottery wares, especially tableware, some imported, and others local dating to the Ptolemaic period, were found. To use the kiln for that purpose, the leftover lime from the previous phase was levelled out to serve as a floor for the storage area. According to the preliminary ceramic study, this phase dated to the Ptolemaic period, implying that kiln C was the workshop's earliest kiln.

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[7] Nicholson 2009, p.2.

[8] Montmollin, Henein 1994, p.71.

[9] This conclusion is based on a personal discussion with Valérie Pichot.

[10] Gosselain 1992, p.244.

[11] Saito 2012, p.69.

[12] Soukiassian *et al.* 1999, p.73.

All three are roofed kilns, evidenced by the existence of entrances to the kilns from one side to load the kilns, that were temporarily closed by pottery sherds and secured and sealed with clay during each firing. These ceilings might have been dome-shaped with some holes to serve as chimneys, based on the ethnographical study of still-used roofed kilns in Egypt[13]. The reason for the partially calcined limestone cobbles inside the firing chamber of Kiln D could be related to a failure to adequately fire the kiln due to its location and orientation. As kiln D is placed in the highest area of the site, not sunk into the ground or enclosed by retaining walls, it was vulnerable to strong winds. Also, the low draw-hole of the kiln is located facing north and the northwest winds would disrupt the firing process.

CONCLUSION

Based on this investigation of the kilns discovered at the Tabbet Metawah site during the 2022 salvage excavation season, it was possible to conclude that Kiln C was the oldest kiln at the site, particularly in the pottery workshop phase, dating back to the Ptolemaic period based on preliminary ceramic studies. Its overall design may have been used as a template for the construction of the more recent. They are all updraft kilns with roofed ceilings and have foundations sunk into the bedrock.
The design of kilns A and B became larger and more intricate during the early Roman Period than the design of kiln C during the Ptolemaic Period. With a unique design of the divided firing chamber, as well as the tunnel leading to the stokehole, this design of kiln has not been observed elsewhere so far.

ACKNOWLEDGMENT

I would like to express my heartfelt appreciation to Dr. Khaled Abo Al Hamd the general director of the Alexandrian Antiquities department for all his support and help during the excavation. The archaeological team of the mission: Aya Salem, Amany Shaaban, Ahmed Shalaby, Amr Wahid Eldin, Mohamed Ramadan, Rania Hamdy, and Iman Adb El-Zaher. Dr. Valérie Pichot for her helpful suggestions both during the excavation and during preparing this paper. I would also like to express sincere thanks to Dr. George Soukiassian and Dr. Paul Nicholson for reviewing the paper and for their insightful comments.

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[13] Saito 2012, p.64.

THE ARCHITECTURE OF THE ANIMAL CATACOMBS IN DENDARA

SYVLAIN DHENNIN
CNRS UMR 5189 HiSoMA

SUMMARY

The animal catacombs of Dendara are located a few hundred metres southwest of the temenos of Hathor, close to the human necropolis and at the edge of the preserved area of the archaeological site. They were fully excavated at the end of the nineteenth century by W.M.F. Petrie, who drew up and published a rather schematic plan of two adobe buildings. He did not publish much more information on the architectural design or construction techniques of these buildings, which he mistakenly dated to a broad period ranging from the New Kingdom to Roman times. The resumption of excavations in this area of the site in 2019 (IFAO/CNRS mission, HiSoMA UMR 5189) has enabled us to highlight the construction conditions of these catacombs. Two phases can be identified. The first involved independent underground galleries built of mud bricks, while the second consisted of main corridors distributing side galleries in which the animals were buried.

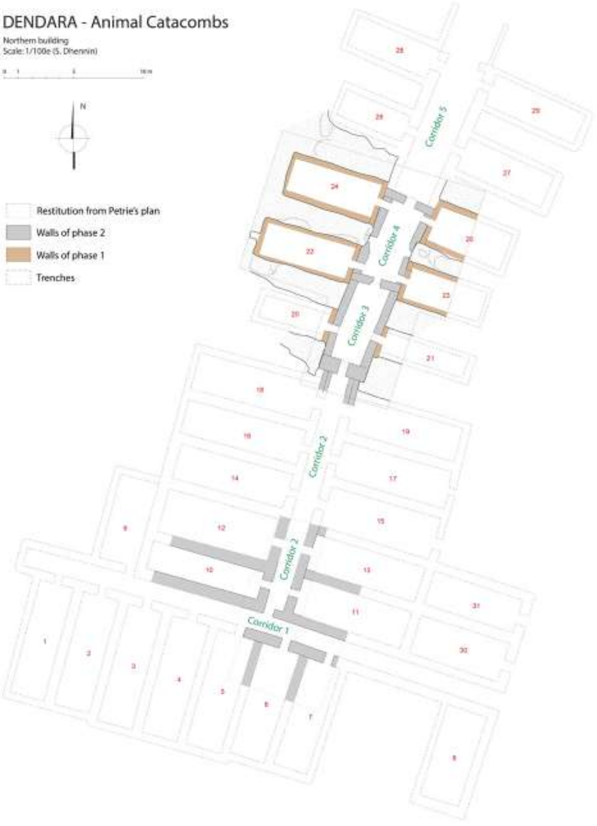

Figure 1: General plan of the Northern building.
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The animal catacombs of Dendara[1] were identified and extensively excavated by W.M.F. Petrie in December 1897. The publication is rather concise[2] but, together with the writings of Flinders and Hilda Petrie in the Journal kept at the Griffith Institute, Oxford[3], it gives a fairly accurate idea of the extent, progress and speed of the work carried out. Within a month, the two main buildings had been completely cleared and a general plan drawn up.[4] This plan, published at a scale of 1:400, contains few details and presents a curious layout. In particular, the northernmost building (Fig. 1), which is the subject of this paper, shows a change in orientation, with the center of the structure moving eastwards. This shift corresponds to a change in the organization of the underground galleries: whereas in the southern part of the building, they are adjacent to each other (gallery 1 to 19), in a uniform and compact architectural design, the galleries further north (gallery 20 to 29) are isolated, built separately from each other and are less regular in size. The aim of the new excavations on this building[5] was, in addition to establishing the general relative chronology, to understand these constructive differences and to highlight the topographical, chronological, or contextual reasons that may have led to this deviation in the plan. The absolute chronology is still uncertain, due to the early excavation of the building, but first observations tend to place it in the Hellenistic period. Two test trenches have been opened to date, one in the southern part and the other in the northern part. The following paragraphs will therefore describe the results obtained by the renewed excavations, first in the southern part and then in the northern part, which have enabled us to review the general phasing of the construction and to clarify variations in the plan.

1. THE SOUTHERN PART OF THE BUILDING

The northern building, oriented north-northeast/south-southwest, is approximately 53 m long, according to Petrie's plan. Its width varies considerably between the northernmost part, 15 to 17 m wide, and the southernmost part, 35 m wide. The southern section comprises all the corridors and galleries to the south of the line formed by galleries 18 and 19. On Petrie's plan, this ensemble forms an architectural unit. In the current numbering of the areas (Petrie did not leave any), it is composed of corridor 1, distributing galleries 1 to 9, corridor 2, distributing galleries 10 to 19 and two additional galleries (30 and 31), which appear to open directly outside the building, to the east.

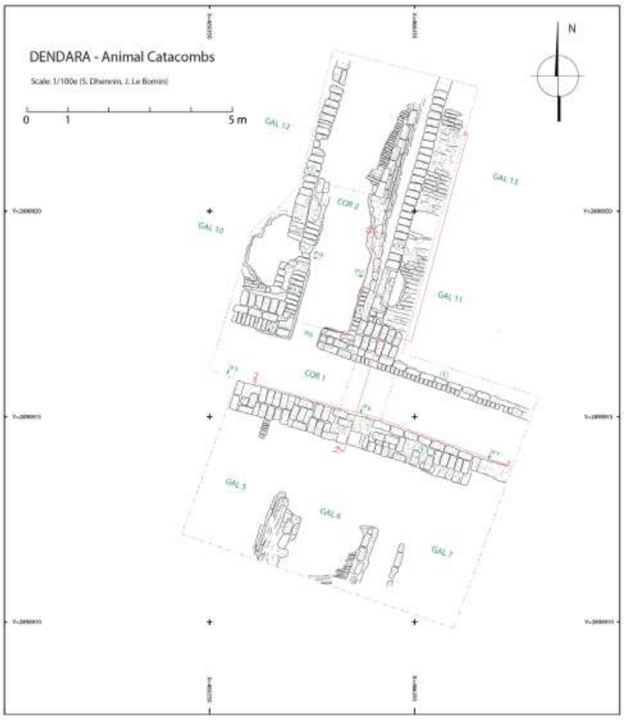
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Figure 2: Top view of corridors 1 and 2.
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The two corridors forming the southern part of the building are arranged perpendicularly (Fig. 2). The first (corridor 1), 1.20 m wide, is oriented west-northwest/east-southeast. It was excavated over a length of 7 m, only in its central section. According to the plan drawn up during Petrie's excavations, this corridor extends for 35 metres and opens onto seven galleries to the south-east and probably onto an eighth gallery to the east, although the plan does not show a door. In the part of the building excavated by our team, the doors and entrances to three galleries were identified (galleries 5, 6 and 7). The south wall of the corridor (wall 4, Fig. 3), like the rest of the structure, is made of adobe. The whole structure was burnt during a fire, giving it the appearance of a clay brick construction, which has enabled the remains to be better preserved. Wall 4, 0.75 m thick, contains the doors to the various galleries (Fig. 4). It is preserved up to a maximum height of 1.70 metres (including foundations). The wall was built with 15 rows of alternating stretchers and headers courses of 35 x 17 x 10 cm adobe, bonded with coarse mud mortar with a coarse plant additive. The thickness of this mortar is irregular and variable, ranging from 1 to 3 cm for the bed joints and 0.3 to 3 cm for the vertical joints. A single bed, laid directly on the substrate, was observed. This substrate is made up of large pebbles, mixed with sand and forming a fairly solid base for the foundation. This foundation was covered by a layer of backfill from the excavation of the substrate (US1032), itself covered by a smoothed raw clay floor, badly damaged by the fire. This floor was only preserved in small sections, running up the walls. The course forming the base of the vault is made of stretchers on the surface of the walls and supported by bricks in the interior of the masonry. It is 1.57 m above the wall foundation. No vaulting was preserved in this part of the corridor. The entire wall was covered with a mud plaster that was reduced to traces by the fire.

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[1] The mission is directed by Matthieu Vanpeene (CNRS, CFEETK). The work at the animal catacombs is supported by the IFAO and CNRS UMR 5189 HiSoMA.

[2] Petrie 1900, p. 28-30 for the description of the building and a sum up of the excavations.

[3] Petrie 1897-1898, p. 22-35. I thank Y. Tristant who brought this document to my attention.

[4] Petrie 1900, pl. XXXVI.

[5] For a general presentation of the catacombs and the work undertaken, see Dhennin 2022.

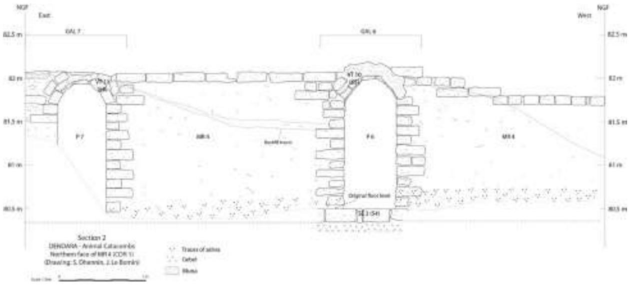

Figure 3: Elevation of wall 4.
© S. Dhennin, J. Le Bomin

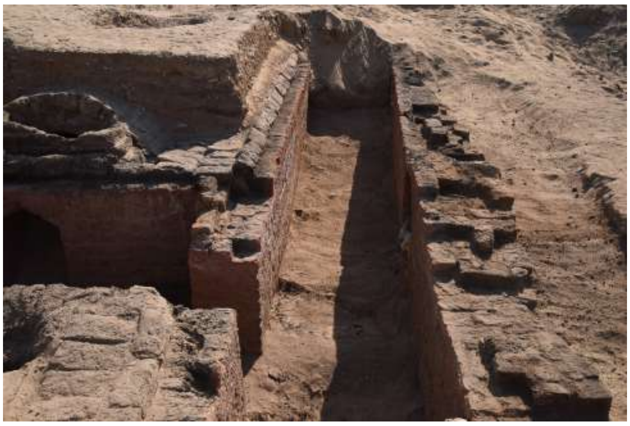

Figure 4: Corridor 1 and corridor 2, from West.
© S. Dhennin

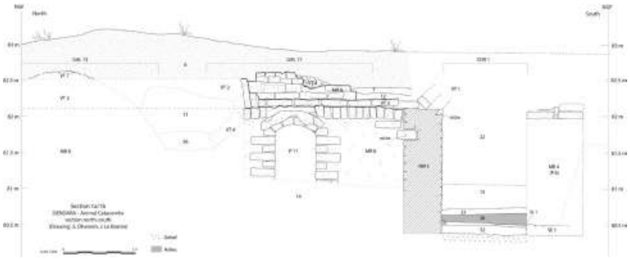

Figure 5: Section of corridor 1 and elevation of corridor 2.
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The northern corridor wall (wall 5) is of similar construction (Fig. 5). It has been preserved up to a maximum height of 1.68m (including the foundation layer) and an elevation of 1.54m. It is 53 cm thick and comprises a total of 15 courses, only one of which is a foundation laid on the substrate, like wall 4. The size of the bricks is identical, as is the thickness of the mud joints. The differences in construction lie in the organization of the corridor vault course and the foundation course, composed of bricks laid on edge, perhaps to make the height similar to that of wall 4. The corridor vault (vault 1), almost destroyed, was still partially visible on wall 5, making it possible to recognise a "Nubian vault".

A door (door 32) was built into wall 5 to give access to corridor 2. To form this doorway, the eastern section of wall 5 was extended westwards by 62 cm, reducing the opening to 60 cm. Immediately below the vault, a small oblong niche is dug into the base of the vault for lighting purposes. A second niche, on the north side of the continuation of the wall, was used for lighting corridor 2.

Corridor 2 was cleared by only 2m to the north, in order to expose the entrance to galleries 10 and 11 and avoid backfilling the excavated corridor 1. Its construction method is similar to that of corridor 1, as is its width (1.20m). The load-bearing walls (walls 6 and 8) are built in a similar way to walls 4 and 5. They were plastered with a mud mortar, of which only a few traces remain on the top of door 11. The foundations of the vault are both made of rowlock. The vault was framed by two parallel walls (walls 7 and 9), whose technique has not been fully clarified: they are probably an extension of the elevation of walls 6 and 8, reduced to half their thickness to frame the vault and serve as buttress walls. Half the thickness of the walls (towards the interior of the corridor) thus forms the load-bearing walls, while the other half of their thickness rises higher, at least up to the extrados of the side gallery vaults, to close the opening and serve as a gable wall (Fig. 6). These walls were also designed to contain the backfill that covered the flanks of the vault, loading it and making the structure underground. This vault (vault 2), partially preserved on the north of the corridor, is a two-course vault with a parabolic arch. The bricks used for this vault are of different modulus for the two courses. The lower course is made up of long, thin, slightly leaning bricks with wide finger marks on the sides. Ceramic sherds are interspersed between these bricks, in a non-regular pattern. The type thus corresponds to a 'Nubian' vault. The upper course is made of the same bricks as the walls, placed perpendicular to the first course. So far, all the vaults observed in the catacombs, both for the galleries and the corridors, have been built using to the same technique.

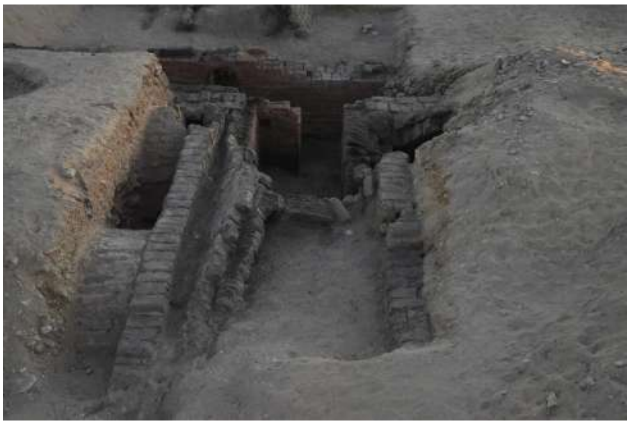

Figure 6: General view of corridor 2, from North.
© S. Dhennin

The entrances to the galleries distributed by the corridors were provided by low and narrow doors. Door 6, for example, which opens onto gallery 6, is 1.50 m high at the arch and 60 cm wide. Its arch is positioned on the eleventh course of wall 4. Its lower course is composed of two series of five headers, separated by two thin bricks (Fig. 7). The whole was mortar-bounded and covered with a thick plaster. The upper course, partially preserved and hidden by mortar remains, had a similar layout. No door-closing system was observed, nor any blocking that might correspond to the closing of the galleries after their filling, was observed.

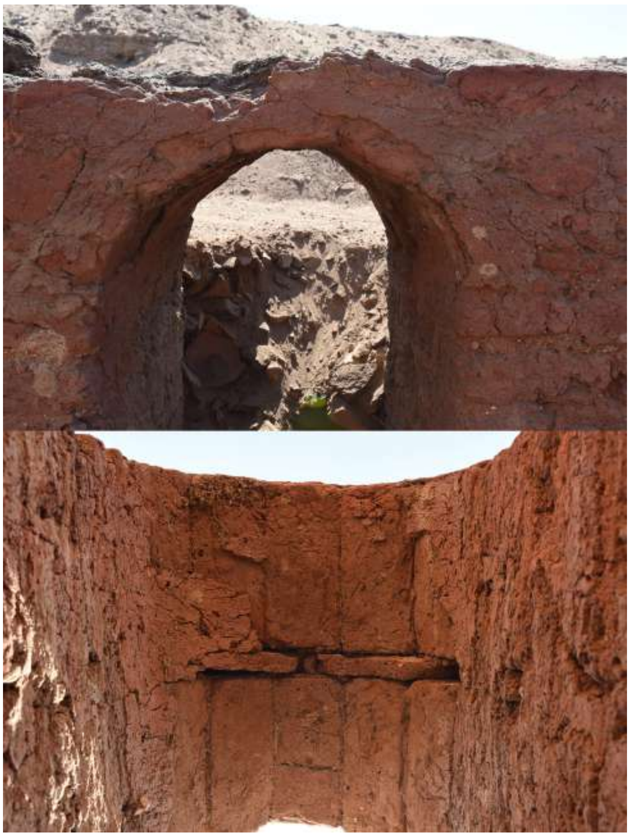

Figure 7: Doorway 6, from North and from below.
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2. THE NORTHERN PART OF THE BUILDING

2.1 THE INDEPENDENT GALLERIES (PHASE 1)

The oldest phase consists of independent galleries that Petrie did not recognize as such (Fig. 8). These are the galleries to the north of gate 33. They comprise a group of ten galleries (gallery 20 to gallery 29), with entrances facing each other in pairs. Their initial access to the underground is unknown. To date, only galleries 20 to 25 have been partially excavated. They were all excavated in two sedimentary layers: the first consisting of slowly accumulated fine silt (alt. sup. 83.62 m, current surface at the top of gallery 24) and the second forming the natural substratum (alt. sup. 81.49 m, consisting of large pebbles mixed with sand). The upper, very compact layer is intersected by several older pits,[6] of undetermined function, found filled with sand and sometimes dug out by the excavation of the galleries. Once the galleries had been dug, their access was closed by adobe walls, each opened by a door, and the sides of the galleries were covered with walls before the vault was built. The organization of the exterior space in front of the gallery doors is not known and the construction of the corridors in phase 2 (see below) prevents archaeological observations.

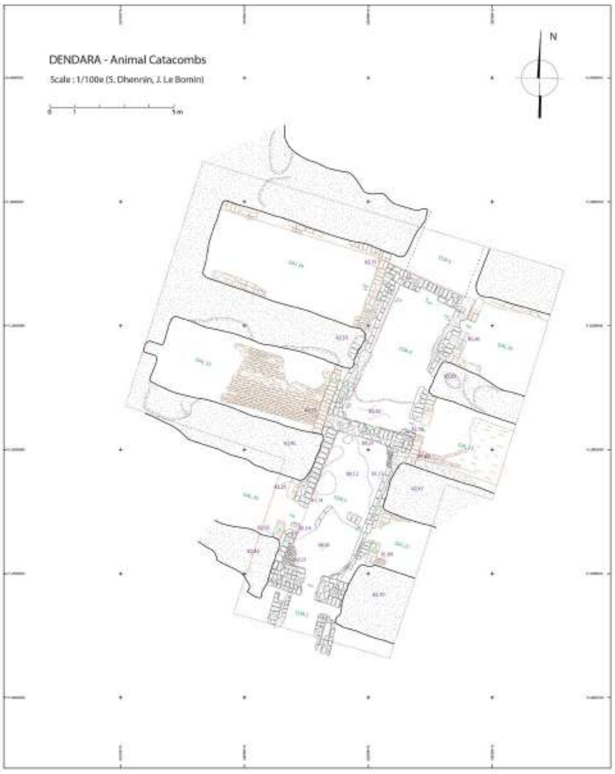
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Figure 8: Top view of corridors 3, 4 and side galleries.
© S. Dhennin, J. Le Bomin

Gallery 24 is the only one to have been fully excavated. It is a rectangular chamber, and the hollow in which it is built measures 3 x 7 m. It is closed by a thin wall (wall 18), made of one header or two stretcher bricks. This wall is interrupted at its centre by a small doorway with a semi-circular arch (door 39), 51 cm wide. The exterior is decorated with a moulded cornice covered with smooth earthen silt plaster. This wall was installed and designed to fit the hollowed-out sides of the gallery. The long sides of the gallery were also covered with adobe walls, connected to wall 18. The south wall (wall 29) is almost destroyed. Only a 2.5 m section remains to the west and a few bricks against wall 18. The north wall (wall 30, Fig. 10) is better preserved, up to the height of the course that supported the vault of the gallery (vault 26), which had completely collapsed. This collapse is old, as no bricks in a demolition position were observed during the excavation. On the other hand, two low, unbonded bricks walls were discovered, blocking the entire gallery in a perpendicular way. These low walls, of recent construction (probably dating back to Petrie's work), covered the north wall (wall 30), so they could only have been put in place after the destruction of the vault, and probably by reusing some of the bricks that made up the vault. Nevertheless, the shape of the vault can be seen in the traces of plaster being torn off at the back of wall 18 (Fig. 9). As with the other galleries, this is a double-supported Nubian vault. The rear (west) wall of the gallery has not been preserved at all and probably collapsed with the vault, unless it was never built. Nor were the bricks of which it was composed found in a collapsed position. This wall may already have been destroyed at the time of Petrie's work, as he depicts it on his plan with a thinner line than the other gallery walls. The other independent galleries excavated (galleries 22, 23 and 25) are built on the same model, although no other cornice decoration was detected. They were all uncovered during the Petrie excavations and are in varying states of preservation. All the vaults have partially or completely collapsed.

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[6] Petrie 1897-1898, p. 29.

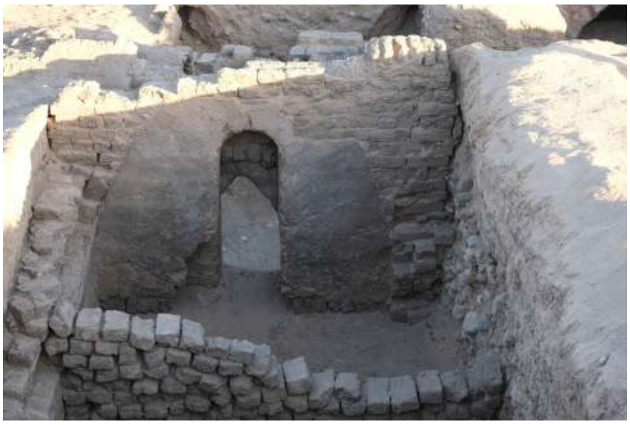
Figure 9: Gallery 24, wall 18 and doorway 39, from West.
© S. Dhennin

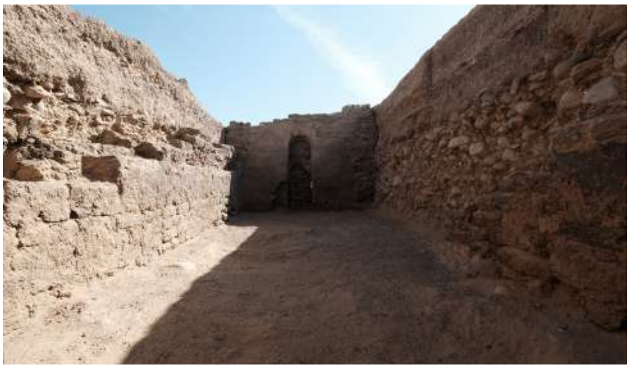
Figure 10: Gallery 24, from the inside (West).
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Based on our observations and Petrie's sketch plan, the ten northernmost galleries (20 to 29) appear to have constituted a first architectural phase, made up of independent galleries, all opening onto a single, probably unbuilt space (Fig. 1). The initial access to this group of galleries has yet to be identified. The connection with the southern part of the building (door 33) as it appears today was made during phase 2 and the northern access to the building has yet to be uncovered. In chronological terms, the ceramic study is still in progress, but preliminary observation of the few sherds collected from the walls and vaults of phase 1 could indicate a dating to the late Hellenistic period.

2.2 THE ADDITION OF CORRIDORS (PHASE 2)

The reasons for the change in plan are not obvious, other than the desire to enlarge the building, which must have made meant remodelling the pre-existing structures in the northern part. The independent galleries were kept, and the circulation space was reorganized by adding doors that divide the space into three corridors (doors 33 to 35). Side walls were built to support the vaults and form the corridors. These corridors were installed while preserving the pre-existing walls to which they abut, which led to architectural adjustments in order to preserve access to the galleries (Fig. 11).

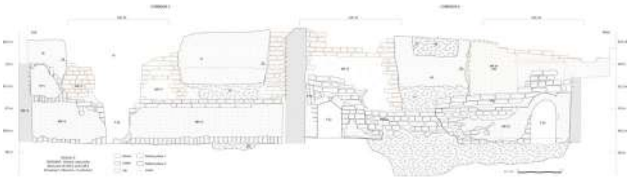
Figure 11: West elevation of corridor 3 and 4.
© S. Dhennin, J. Le Bomin

Corridor 4 (Figs. 8 and 12), for example, is bounded on the north by gate 35 and on the south by gate 34. It was completely uncovered during Petrie's excavation, when he dug to a depth of 70 cm deeper than the ancient floor (SL3/US1113) over most of the corridor. Only a strip of earthen floor (alt. 80.25 m) with an irregular surface (probably due to the earlier excavations) was preserved to the south of the corridor (Fig. 8). This excavation of the floor led to a partial collapse of the corridor's side walls to the east (wall 20) and the west (wall 22), taking with them the vault that covered it (vault 8). The remains of the vault, found in a collapsed position during excavation, indicate that it was still present at the time of Petrie's excavations. It is a double-course Nubian vault, of the same type as those found in corridors 1, 2 and 3. Its sides were filled with a layer of large pebbles from the substrate, still partially present to the west, against wall 18.

Walls 20 and 22 are similarly built. They are low load-bearing walls (height 0.81 m), designed to delimit the corridor while supporting the vault ceiling. They are made of 35x17x10 cm adobe, with alternating courses of headers and stretchers. The west wall (wall 20) is founded at an altitude of 80.19 m and the east wall (wall 22) at an altitude of 80.11 m. The foundation, laid directly on the substrate, consists of headers. The entire wall was protected by a fairly coarse clay plaster, which held up well. The west wall is pierced by two openings (doors 22 and 24) that were aligned with the pre-existing gallery doors (doors 37 and 39) (Fig. 11). These openings are the same width as the earlier doors, but lower, necessitating masonry adjustments. Whereas the doors of phase 1 had round arches, those of phase 2 are of the double-sloped type. Door 24, for example, has a roof composed of 2 x 7 bricks arranged in two slopes on either side of a central ridge brick. The thickness of the plaster gives the whole a roughly rounded shape from the outside (Fig. 13). The presence of this opening has disrupted the external layout of the vault corridor, with several headers and one shiner above the opening. The empty space between the top of the old door and the extrados of the vault was filled with bricks to prevent sand from seeping in once the structure was covered.

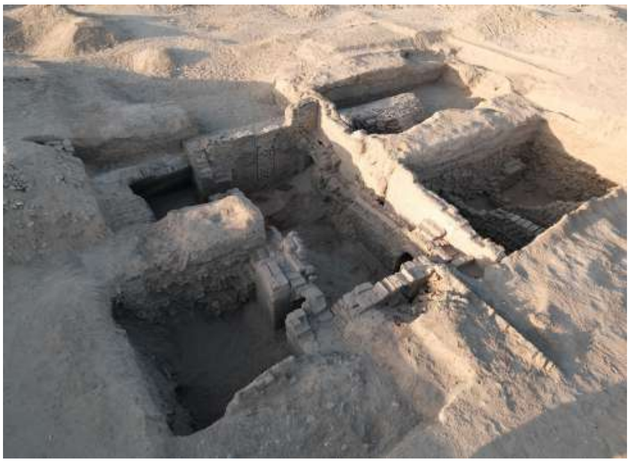

Figure 12: General view of corridor 4 and side galleries, from North-East.
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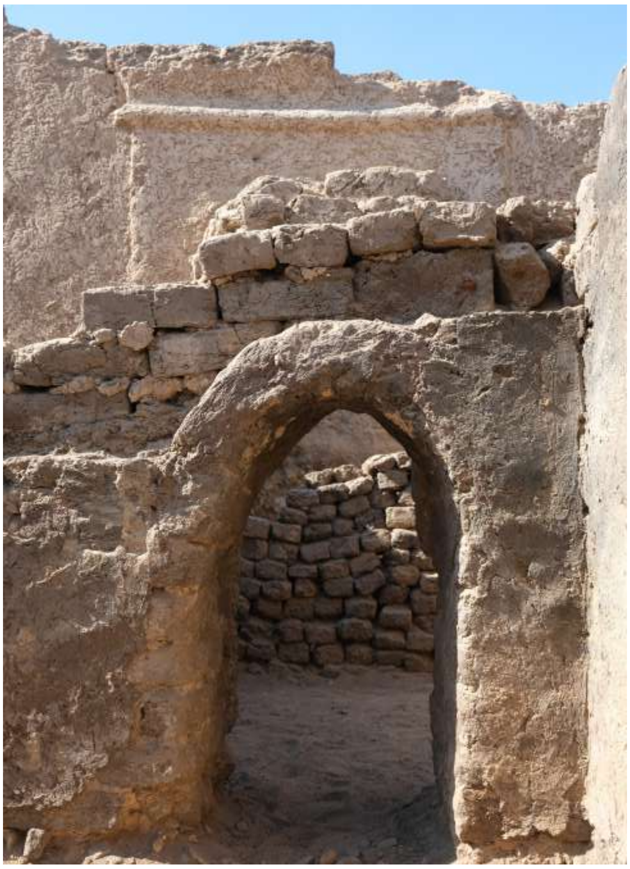

Figure 13: Gallery 24, doorway 24, from East.
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The general phasing of construction has now been definitively established, at least in relative chronology. The first phase consisted of the excavation of galleries 20 to 29 in the bedrock and building them in adobe with Nubian vaults. The levels associated with the use of these spaces have not been preserved and therefore do not allow us to establish their absolute chronology. The second phase involved the addition of corridors (3, 4 and 5) to allow circulation between the galleries. When the corridors were built, all the gallery doors were doubled inwards. This was made necessary by the addition of load-bearing walls for the corridor vaults, which resulted in a narrowing of the space. The intermediate doors delimiting the corridors to the north and south (doors 33, 34 and 35) also belong to this second phase, which combined previously independent galleries into a single building. The levels of use in this phase were almost all excavated and destroyed during Petrie's work. A third phase corresponds to Petrie's excavations, up to the present state of the structure. In addition to the exhaustive excavation of the galleries and corridors, this phase includes Petrie's reoccupation of the galleries for his team, which is mentioned in his archives. The southern part of the building, on the other hand, was built in a single phase, probably in the same operation as the addition of the corridors.

The Dendara catacombs are not the most common model for animal burials in Egypt. Animal burials were most often, but not exclusively, carried out in galleries dug into the rock, in re-used human tombs or in open spaces. Other catacombs, however, were built of mud brick, one of the most recent to have been excavated being Quesna, in the western part of the Delta[7]. It was also composed of underground galleries built in adobe, but preliminary publications do not yet allow for precise architectural comparisons. The example of Dendara remains one of the best preserved, from the architectural point of view, and the one best able to illustrate the construction methods of this type of underground structure.

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[7] Rowland *et al.* 2013.

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TESTIMONIES OF COOPERATIVE CARE: A SOCIOECONOMIC SYSTEM OF MAINTENANCE OF THE OLDEST MOSQUE IN SUDAN

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SUMMARY

This paper presents preliminary results of ethnographic research on how local communities have contributed to maintenance of a historic religious building in Sudan with a brief summary of the history of modern conservation of the building. The so-called Old Dongola Mosque is a two-storey building, and the oldest standing mosque in Sudan. The building was originally built in the 9th century as a church or throne hall and suffered significant damages in the 13th and/or 14th century. It was converted into a mosque in 1317. The building was used as a place of worship until 1969. It went through a number of modifications, additions, and repairs in its long history. Semi-structured interviews were conducted in the immediate vicinity of the Old Dongola archaeological site, an area in which direct descendants of the inhabitants of Old Dongola live, to understand the socio-economic aspect of the maintenance and role of the local communities in the building's upkeep. The local narratives and memories encapsulate who played a significant role, how materials for past repairs were selected, and who participated in the process, along with discussion of the importance and users of the building.

INTRODUCTION

Local traditional technology and knowledge of materials and methods are important sources of information for modern conservation practice in a specific social, cultural and environmental context. Understanding traditional conservation and management systems in various social contexts is also increasingly studied to explore methodologies for participatory, sustainable heritage conservation and management.[1] In conjunction with the Baraka project, a new conservation and management project of the mosque at Old Dongola, the authors explore values of the building in local communities around Old Dongola in northern Sudan (Fig. 1). This paper is based on preliminary results of part of the study, focusing on the socioeconomic system relating to maintenance of the building that has been preserved for over 1100 years and served as a mosque from 1317 to 1969 CE. It is the oldest preserved mosque in Sudan, and its significance is closely tied to the history, culture and faiths of the populations in the vicinity and Sudan at large.

The Baraka project is an international multidisciplinary project implemented in cooperation with Polish institutions and the Sudanese National Corporation for Antiquities and Museums. The approach is holistic and participatory in all aspects (documentation, conservation, management); ultimately, the project will design a new exhibition and presentation scheme to efficiently convey its importance and stories of the heritage building to Sudanese and international audiences. This article is based on a series of interviews that took place in the village of Ghaddar between November 2022 and February 2023. In total 19 interviews were conducted by the authors, and were transcribed and translated by Siedahmed.

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[1] e.g. Sidi 2012; Wijesuriya *et al.* 2016.

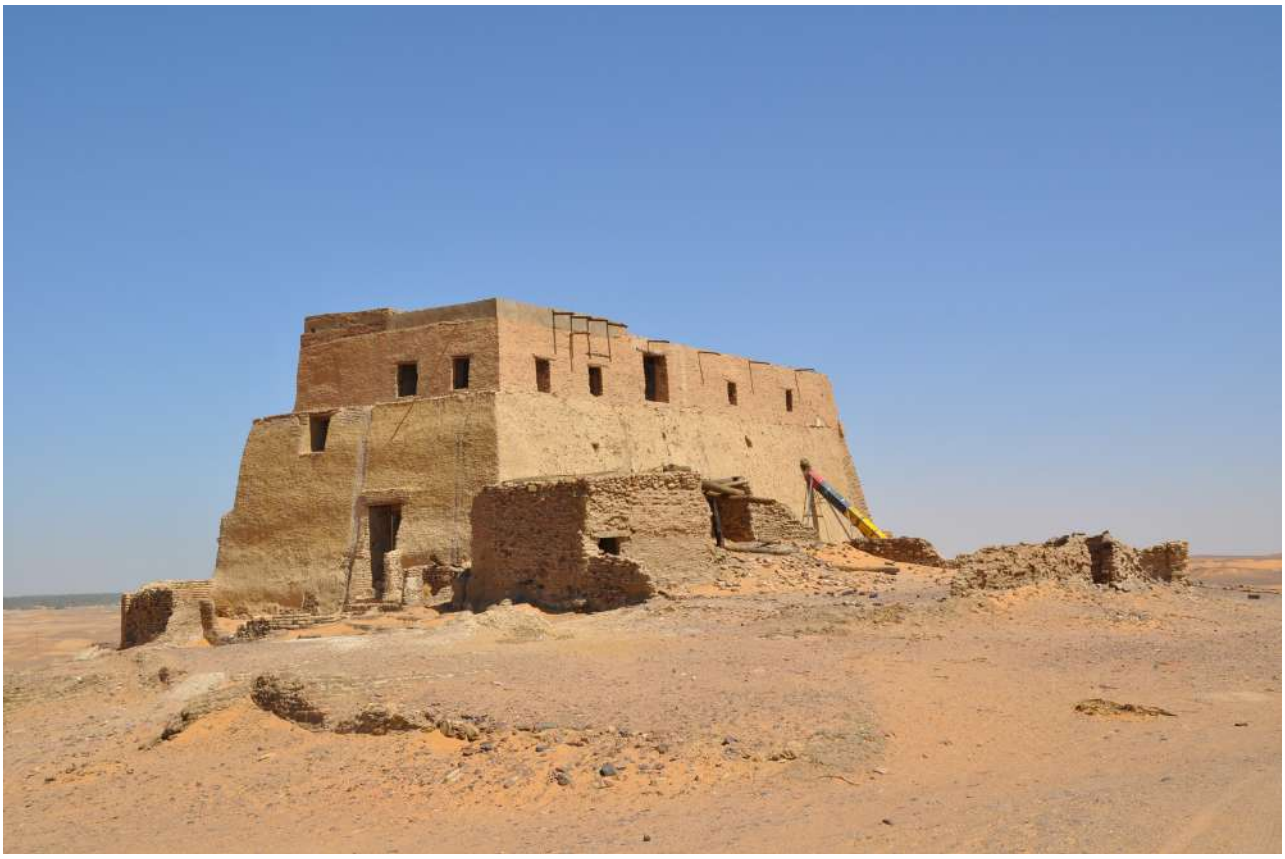

Figure 1: The Old Dongola Mosque, a view from the southwestern side.
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1. OLD DONGOLA

1.1. THE LOCATION AND SITE HISTORY

Old Dongola (originally Tungul) is located on the right bank of the river Nile, between the Third and Fourth Cataracts, ca. 350 km north of the capital, Khartoum, in the Republic of Sudan (Fig. 2). The archaeological site occupies an area of 2.81 sq.km, encompassing the settlements of the Makurian, Funj and modern periods, Christian and Muslim cemeteries, churches, monasteries, the Citadel and the mosque (Fig. 3). Scientific investigations of the site began in 1964 by University of Warsaw[2] and continue today.

The history of Old Dongola goes back to the late 5th century CE when the capital of the Kingdom of Makuria was founded,[3] and was inhabited until around the turn of the 20th c. Makuria was one of the three Nubian Kingdoms that emerged around the late 5th c., with the royal court converting to Christianity by the mid-6th c.[4] The Makurian capital developed into one of the most important African mediaeval cities between the 9th and 11th c.[5] However, it was gradually weakened by repeated invasions of Mamluks beginning in the late 12th c., with the royal court finally fleeing the capital in 1365,[6] subsequent to which a royal member who converted to Islam took the throne. Old Dongola remained an important economic and political centre as a city-state or *mekdam* subordinated to the Funj Sultanate from the 16th c. The city was also known for its important role in the teaching of Islam in northern Sudan, with many *shuyūkh* (plural of sheikh) or *faqura* (holymen, singular: *faqir*) having travelled to and resided in Old Dongola.[7] The last inhabited area of the site, called Hila Dongola (also known as the Abandoned Village), is located south of the Citadel.

1.2. LOCAL COMMUNITIES

According to the modern administrative division, the site falls within the Old Dongola Unit, Goulid District in the Northern State. The Unit includes 10 villages, with the combined population being over 30,000. Hila Dongola is no longer inhabited, but it maintains cultural, and ancestral links with modern villages in the vicinity, in particular, Ghaddar, Bokkibul, Hammur, and Ghaba (Fig. 2). Many former residents of Hila Dongola relocated to these villages sometime between the 19th and mid-20th c. Among the former residents, several

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[2] Michałowski 1966.

[3] Godlewski 2013, p. 7.

[4] Obłuski 2021a.

[5] Godlewski 2013.

[6] Vantini 1975, p. 699.

[7] MacMichael 1922; Edwards 2004, p. 253.

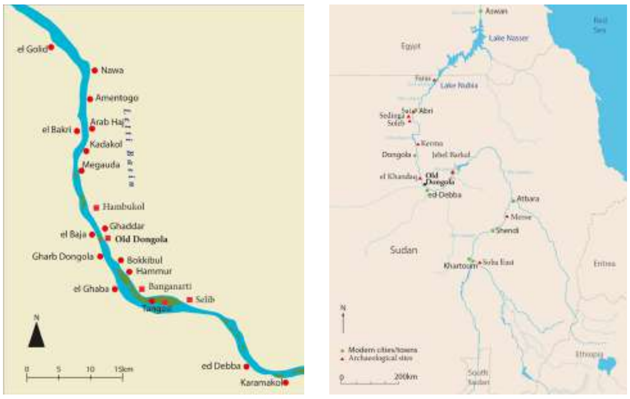

Figure 2: A map of the Sudan (right) and a map off the local area around Old Dongola (left).
© T. Fushiya

prestigious families whose ancestors were powerful leaders and sheikhs during the Funj period, are mentioned in *al-Tabaqat* (biographies of holymen), *nisbah* (a record of genealogy)[8] and textual evidence found during the recent excavations. For instance, the descendants of King Kashkash in Ghaba, and the *qadi* (judge) Suwar el Dahb in Ghaddar. *Qibab* (domed tombs, singular *qubba*) and *baniya* (structures associated with a sheikh(s)) mark the most evident aspect of ancestral ties between Old Dongola and the local communities. Important *shuyūkh* were buried in the Muslim cemetery of Old Dongola under a *qubba* or *banya* (Fig. 4). When a member of the decedent family of a sheikh dies, he/she is buried in a grave close to his/her ancestor's *qubba*, while some local inhabitants make ceremonial visits to a *qubba* for a festivity or *baraka* (blessing).[9] In addition to the familial continuity, ongoing archaeological research has identified threads of continuity in the knowledge of techniques, uses and raw materials utilised for daily objects in the local communities, providing additional opportunities for collaboration with local communities in archaeological research.[10] The close ties of the local populations with Old Dongola means that, for the local communities, the mosque of Old Dongola also holds a significant value beyond a spiritual sense. At the occasion of *Eids* (Islamic festivities), local families still make a visit to the mosque after the first *Eid* prayer.

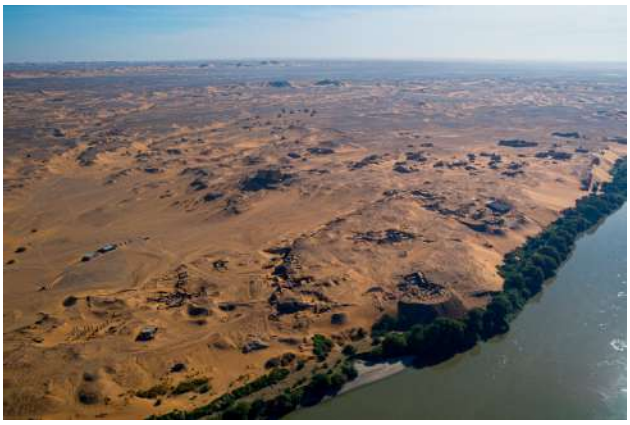

Figure 3: The archaeological site of Old Dongola.
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2. THE BUILDING OF THE OLD DONGOLA MOSQUE

2.1. THE MOSQUE

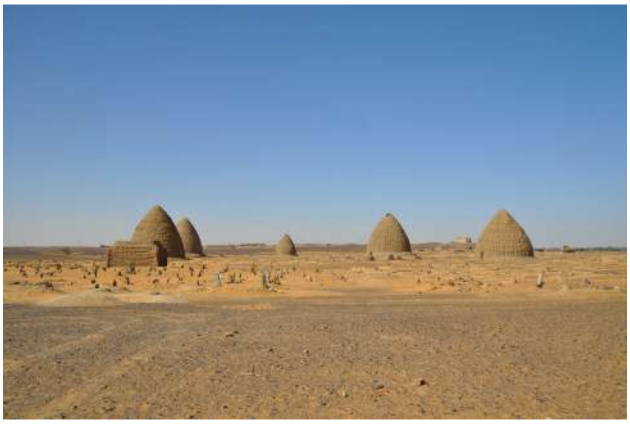

Figure 4: Qibab (domed tombs) and banya of shuyukh in the Muslim cemetery of Old Dongola.
© PCMA, UW, T. Fushiya

The Mosque of Old Dongola stands at the edge of the sandstone outcrops between the Citadel and the Muslim cemetery. It is a two-storey rectangular building, measuring 28 m x 18 m with a height of 12 m (Fig. 5). The ground floor consists of five narrow rooms (U2, U4-7), two large corridors (U1, 3), and a small space (U9) next to a semi-circular tower (U8). The ceiling is high (ca. 6.6m) and the narrow rooms and large corridors have barrel vault ceilings. All of the spaces are filled with rubble up to 4m from the original floor. The ground floor originally had a dedicated entrance(s), though the location(s) of it/them has not been confirmed. Archaeological evidence indicates two doorways were probably on the northern side.[11] The first floor is accessed by a large staircase (U12) on the western side of the building. A square-shaped central hall (c. 8.6 x8.7 m, U18) on the first floor is surrounded by four corridors (U17, 19, 20, 23), having three granite columns and one wooden column supporting the ceiling. The ceiling is 3.1 m high and flat. Located on the eastern side are the semi-circular tower (U21) and a small room (U22). The staircase also leads to the roof.

The lower part of the building, including the vaults, is mostly constructed with sun-dried bricks. Fired bricks were used for places like windows and corners. The outer surface is covered with a material locally called *zibāla* (silt mixed with animal dung and chaff), while the walls in the interior of the ground floor appear to be plastered. One of the narrow rooms (U5) preserves whitewashed walls with a black line. The upper part of the building is built with fired bricks. Today, it is roofed with a traditional roofing structure that uses *jarīd* (palm fronds), *zibāla*, and *birsh* (mat made of palm leaves), supported by wooden beams and the floor supported by doum palm trunks. The roof and some parts of the floor are the most intensively repaired areas in the building in modern times. The walls of the central hall on the upper floor and some parts of the staircase preserves polychrome paintings depicting biblical scenes, Archangel Michael, saints and royal and ecclesiastic figures.[12] These paintings were covered by plaster layers and have been removed in the past hundred years. Sandstone blocks were applied in some parts of the building, such as at corners and the bottom of the building, thresholds, lintels, door jambs, column bases, steps, and flooring on the first floor.[13]

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[8] MacMichael 1922.

[9] Fushiya 2021a.

[10] Fushiya 2021b; Obłuski, Dzierzbicka (eds.) 2022.

[11] Godlewski, Medksza 1987.

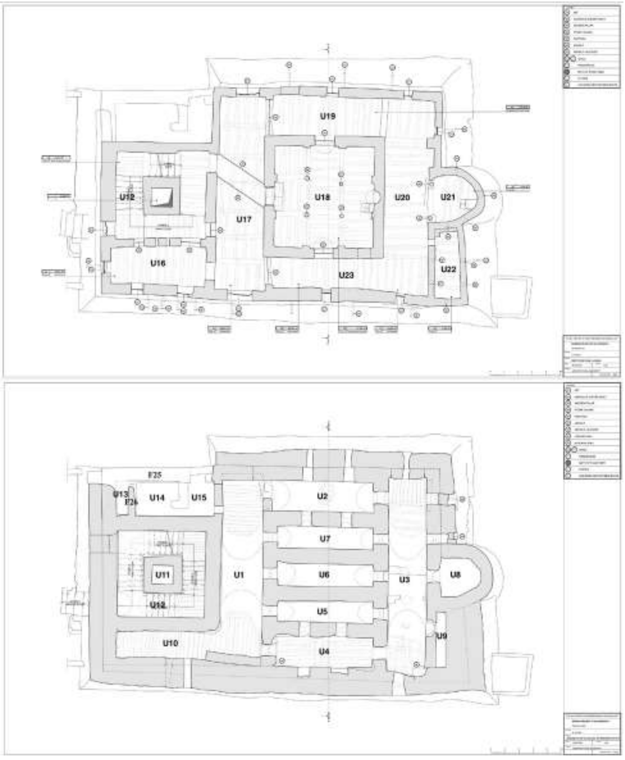

Figure 5: The plans of the mosque; the ground floor at the window level (below), the first floor (above).
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2.2. HISTORY OF THE BUILDING

The original construction of the building is dated to the beginning of the 9th c.[14] However, the original function of it is still under scholarly discussion. It has been suggested as a church or royal throne hall, while the function of the ground floor may have been storage, based on the character of palatial architecture in Makuria.[15] The building was converted to a mosque in 1317 CE (717 AH) and functioned as such until 1969. The abandonment was due to safety concerns over the structural stability. From the 19th c. onwards, the building was mentioned by European travellers and scholars[16] as the most distinctive architecture in the area, identified as a mosque, or church. The interior of the ground floor was investigated between 1971 and 1980 by the Polish team, although the archaeological explorations had to be limited due to the structural instability.[17]

The building underwent multiple alternations, rehabilitation and repairs over the past 1100 years.[18] During the Makurian period, it appears that the royal court had a crucial role in the decoration and presumably maintenance of the building,[19] and the walls of the central hall were decorated one or more times, as 1-5 painted layers were found.[20] The building's structure suffered significant damages a few times, probably in the 13th and/or 14th c. Two layers of hardened mud floors were found at two different levels above the original floor, both laid on top of rubble and sand. It is likely that the debris was from the collapsed parts of the building and filled with sand to create a new flat surface.[21] The last major damage likely caused the collapse of the north-western part of the building, resulting in a wall (F25) being rebuilt and buttresses added. As the height of the floor was raised, the upper windows of the narrow rooms (U4-7) were widened and used as doorways. The opening that is used to enter the ground floor today is also located at the same height. Such reconstruction, reinforcement and creation of the floors are the signs of efforts to continuously use the building despite the major damage.

After the conversion of the building to a mosque, the most notable features of change were the additions of a *minbar* and *mihrab* in the central hall (Fig. 6), placement of a stone stela that records the conversion, and the wall paintings being covered with plaster. An Arabic inscription was left near the

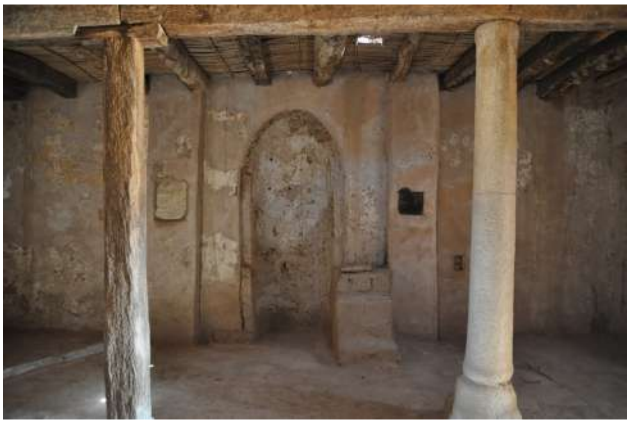

Figure 6: The central hall.
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[12] Martens-Czarnecka 2001; Zielińska 2015.

[13] For details, see Godlewski 2015; Godlewski, Medksza 1987; Terlikowski *et al.* in this volume

[14] Godlewski 2013.

[15] Godlewski 1982, 2013, p. 47.

[16] See Obłuski *et al.* 2013.

[17] Jakobielski 1978; Godlewski 1982.

[18] Jakobielski 1978; Godlewski, Medksza 1987; Obłuski *et al.* 2013.

[19] Innemée, Zielińska 2018.

[20] Calaforra-Rzepka *et al.* 2015; see also Skarżynska, Chmielewski in this volume

[21] Jakobielski 1978.

entrance to the staircase on a plaster layer that coated the Christian paintings. The structural instability was a long-term concern, especially on the south side. The vaults of U10 and a southern part of U1 collapsed at some points, and then additional walls were built against the original southern wall to support it. The wall at the southern end of U1 looks like it was constructed in haste and built after the floor level was raised to the current level. The ongoing Baraka project will reveal the nature of structural modifications and the chronology.

2.3. MODERN CONSERVATION WORK

The building was subjected to conservation work in the modern era. As the building falls into the category of "antiquity" defined in the Antiquities Ordinances of 1905, it was under the care of the Anglo-Egyptian Condominium administration. The plan of the building was created in 1905 by W. McLean.[22] Reports of the Sudan Antiquities Service (SAS) provide brief notes about the condition of the building and their conservation activities. The works were financed by the district of Merowe based on the request made by SAS,[23] and occasionally supervised by a Sudanese SAS officer dispatched from Khartoum.[24] Repair of the roof and prevention of the entry of jackals into the building, which made holes on the roof, were the focus of their conservation efforts in order to reduce damages caused by rain.[25] Not many details of the work are noted in the report, but the records of conservation work for the roof in 1923, 1939, 1944/45, 1946, and 1954-55 indicate how frequently roof repair was necessary.[26] In 1955-56 more significant conservation interventions were made. SAS carried out re-roofing, repair of the staircase and the floor of the first floor by replacing wooden beams that were affected by termites; three doors and three windows were covered with wire-mesh to prevent bats.[27] The eastern part of the floor of the upper level was most probably also refurbished in this period. As discussed below, involvement of local religious authorities and workers may have contributed to choices of the conservation methods and materials.

Since the University of Warsaw was granted the concession of the site in 1964, partial structural repairs[28] have been carried out by the Polish team when necessary. For instance, according to a local builder, he was commissioned to repair a small area of the roof with *jarīd* and *zibāla* and one of the northern windows on the ground floor in 1996. The exterior surface of the building was plastered with *zibāla*, and a temporary protection was made on the roof in 2009 by the Department of Conservation, National Corporation for Antiquities and Museums (NCAM).[29] The last major interventions to the building were a project to renovate the building to be more secure and accessible to visitors in 2014-2017.[30]

3. MAINTAINING THE MOSQUE: LOCAL PERSPECTIVES

3.1. THE MOSQUE OF OLD DONGOLA

Surrounded by ruins, the continuous use of the building was obviously the most important factor that allowed the so-called Old Dongola Mosque to survive into today. After the building's conversion into a mosque, its symbolic and community values likely drove the maintenance efforts. Sheikh Mohamed Sati, the current Imam of Ghaddar, recalls that the mosque was the only *jumaa* (Friday Mosque) in the Old Dongola area (Fig. 7). Inhabitants not only from the immediate vicinity (i.e. Hila Dongola, Ghaddar, Bokkibul) but also from Ghaba across the river, and as far as Tangāshi (13km upstream) came to gather for the Friday prayer. Sheikh Mohamed also indicated the existence of a *masjid* (mosque) at the *khalwa* of the renowned sheikhs Suwar el Dahab and Ghulamallah in Hila Dongola. Daily prayers other than the Friday prayer took place at the *masjid*.

Figure 7: Sheikh Mohamed Satti speaks about the history of the mosque with Siedahmed.
© PCMA, UW, T. Fushiya

However, it seems that the Old Dongola Mosque was not always open to every worshipper. For instance, a woman from Ghaddar confirmed that only men prayed in this mosque. Satti Mohamed Ahmed, a 90-year-old from Ghaddar who had never prayed in the mosque, said he prayed at a *masjid* (mosque) of the *khalwa* of his grandfather. He explained that the Old Dongola Mosque was reserved for the Friday prayer of sheikhs and those who studied in a *khalwa*. Conversely, a visit to the mosque was open to anyone when the mosque guard was available to open the entrance door. A woman from Ghaddar remembers that heritage objects such as a *mufraka* (wooden stirrer), *ibrīq* (water jug), *mulāq* (a device to hang a pot from the ceiling) which were said to belong to the daughter of the Prophet Mohamed, Fatima, were hung from the walls of the staircase, and she saw the objects during her visit.[31] She also remarked that the community was considering having an exhibition of heritage objects in the mosque.

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[22] Crowfoot 1954; Shinnie 1955.

[23] Arkell 1939, 1944.

[24] Chittick 1955, Vercoutter 1956.

[25] Arkell 1939–1946.

[26] Arkell 1939, 1944, 1945, 1946; Chittick 1955.

[27] Vercoutter 1956.

[28] Also, systematic conservation of wall paintings was conducted, see Martens-Czarnecka 2001; Calaforra-Rzepka *et al.* 2015.

[29] Godlewski 2012.

[30] Tarczewski, Dziedzic 2015; Tarczewski 2018.

3.2. MEMORIES OF THE LOCAL COMMUNITIES ABOUT THE MOSQUE MAINTENANCE

The interviews identified two different entities that had significant roles in the maintenance of the mosque. One is the government and the other is the local communities. Satti Mohamed recalls that maintenance work was supervised by engineers sent from Khandaq. The government officers brought with them maps and work tools as well as the budget for food and drinks to stay in the site during the work. A stone slab embedded in the floor of the central hall records one of the maintenance projects during the Anglo-Egyptian Condominium period. It says; the *nāib* (deputy) of *māmūr* (an officer under the district director) of Debba, Ahmed Taha, conducted a restoration of this monument (*athār*) in 1325 AH (1907-08 CE). Workers from Ghaddar were involved in the maintenance efforts, according to Satti Mohamed. A local person was appointed as a guard of the mosque by the government. He was in charge of the entrance key and regular cleaning of the mosque during the Condominium period and lived in a house at Hila Dongola. His descendants continue to manage the building as a guard, hired by the National Corporation for Antiquities and Museums.

Explaining about the government's role, Satti Mohamed also pointed out the significant role played by local religious authorities, especially the Suwar Dahab family. The Suwar al Dahab family took a major role in taking care of the mosque, likely longer than the community's living memories recall. The family is the descendants of *faqi* Mohamed ibn ʻIsa who was a native to Old Dongola and was appointed as qadi in 1684 and was bestowed the title, Suwar al Dahab (Golden Bracelet)[32] by the king of the Funj Sultanate. In the second half of the 18th c., Sheikh Sati Hamid Suwar al Dahab is said to have begun a major renovation of the building.[33] The abovementioned restoration work by Ahmed Taha in 1907-08 is considered as the end of the series of renovations started by Sheikh Sati Hamid. J. W. Crowfoot, who visited the site in 1905 and 1926, indicated that, "the site of Old Dongola actually still belongs to one branch of this family".[34]

What was repeatedly heard among the interview participants was about the building's appearance, that is, it has not been changed over time. This statement might be a repercussion of a recent previous renovation work that altered the appearance. Yet, historical drawings and photographs inform us that no major change in the shape of the building has occurred over the past two hundred years. It may be because past works were limited in scope. El Nour Ali Salih remembers that past works were limited to small repairs and replacement of wooden beams that fell down from the ceiling/roof of the upper floor. Sheikh Mohamed stressed how the shape of the building was not changed over time during past repairs led by the Suwar al Dahab family. He recounted a story heard from one of the local sheikhs. The building had no exterior plastering at one point in its recent history and it was decided to plaster the surface with *zibāla*. He remarked, even this time, the shape of the building was not modified.

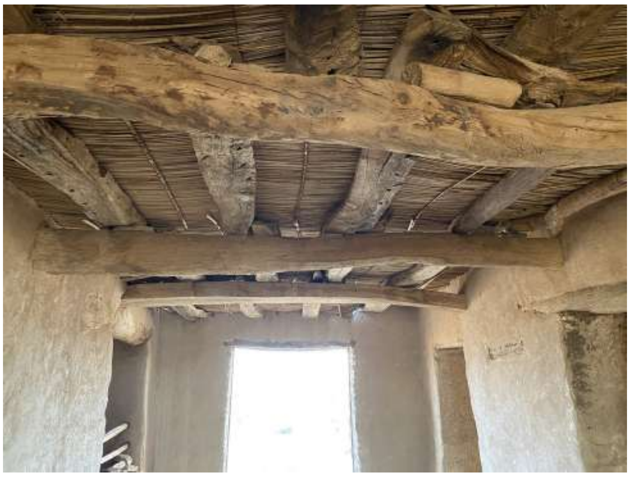

Figure 8: Reuse of a wooden boat as a roofing material.
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Materials used for the maintenance were what was readily available at the moment. When building materials were replaced or fixed, it appears that the exact same materials were not always sought. Sheikh Mohamed told us that wooden beams for the mosque were once obtained from a boat of Sheikh Mirghani Suwar al Dahab who donated them to fix a part of the fallen roof (Fig. 8). The need to dismantle a boat implies that no other materials were available at the time, as well as the importance to the community of maintaining the building. While the type of the wooden beams used in the mosque vary, most of them are locally derived. However, to make a beam a certain length is required, and it ideally has to be a uniform width to recreate a flat surface. Doum palm beams that currently support the floor of the first floor are around 0.3 m in thickness and 3-5 m in length. Beams of this size are not available in abundance in the surrounding villages today; a similar situation was likely to have been the case in the past. The choice of materials was probably related to the urgency of the repair work as well. ElNour described that when people gathered for prayer and found any damages, they immediately took action to prevent further damage. The participants doing the repair work brought everything available to complete the work. Since some of the users of the mosque came from distant villages (a half day journey by donkey), it can be imagined that a minimum period of time was spent to collect materials and implement the maintenance work, unless the government's support was available to purchase materials and hire an additional workforce.

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[31] It appears that the locals were recreating a sacred landscape around Old Dongola. A few stories are known. For instance, the authors heard a story about a hill called Jebel Sit Aisha in Hammur. It is locally associated with the place where the Archangel Jibreel (Gabriel) took the Prophet and some traces of the event were left on the jebel. Bashir recorded a story of a symbolic practice of throwing stones at a house of the irreligious located between Old Dongola and Bokkibul (2003).

[32] Obłuski 2021b.

[33] Obłuski *et al.* 2013.

[34] Crowfoot 1927, p. 143.

While the cooperation of different local people was evident in the maintenance work, *nafeer* may not have been organised specifically for such urgent, small repair work. *Nafeer* is a Sudanese Arabic colloquial term that means working together, and is a cooperative system to support one another in Sudan. Neighbours, extended family, and friends come together to help on an occasion such as the construction of a house and harvest, offering labour, money and/or food. Unlike today when women clean a local mosque on Thursday, women did not participate in the maintenance of the mosque in the past. In northern Sudan, especially in the Nubian area, plastering of the floor and exterior surfaces of private houses is traditionally taken care of by women.[35] In the interviews, it was clearly stated that the plastering of the exterior surface of the mosque was carried out by a group of men, using wooden scaffolding.

CONCLUSION

This preliminary ethnographic study provided insights into the community's views, use, and involvement in the maintenance of the building. While the leading role of an important local family is certain, the "community" that was possibly involved in the repairs and maintenance extends over a wider area, beyond the immediate vicinity. During the interviews, it was also revealed that descendants of Suwar el Dahab also live in villages further afield. This means the possibility of further knowledge and memories that can be collected for this research exist. Further, the use of the building for prayer by a specific group of people who held Islamic knowledge and the display of ethno-religious objects sheds light on a practice of the faith in the local communities and the meanings of the building. These characteristics may have influenced the practice of building maintenance. Further research is required to clarify these aspects.

ACKNOWLEDGMENTS

While we were working on this paper, a war broke out in Sudan. It has immensely affected the lives of our friends, colleagues and all the Sudanese people. Heritage is also in grave danger, especially those in the conflict areas. We call for cooperation and effective actions of Sudanese and international organisations to protect important Sudanese heritage. We stand by the Sudanese people and urgently call on the end of the terrible violence.

The Sudanese National Corporation for Antiquities and Museums (NCAM) has granted permission to PCMA, UW to conduct the research at Old Dongola. This research was funded by CRAC Small Grants XIII, University of Warsaw. Thanks to the ALIPH Foundation, the "Baraka: Revitalization of the Oldest Preserved Sudanese Mosque at Old Dongola project" is being implemented. The Baraka project is led by Artur Obłuski (PCMA, UW). The ethnographic study was approved by the Rector's Committee for the Ethics of Research Involving Human Participants of the University of Warsaw, and all the persons mentioned in the article consented to the disclosure of their personal names. We also thank the anonymous reviewers for their comments.

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DIALOGUE BETWEEN TWO SITES: THE EXPERIENCE OF PROTECTING THE EARTHEN GREAT WALL IN CHINA

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SUMMARY

Both China and the Nile Valley have a large amount of earthen architectural heritage. In the arid regions of northern China, there is the Great Wall of earth on the desert; similarly, Egypt has a large desert, and there are also earthen fortified structures on the desert. Their materials, structures, and problems are similar. As earth material is more fragile than brick and stone, the rammed earth wall faces greater challenges from environmental change than the brick wall. In addition, the preservation status of rammed earth walls is precarious. This article reviews the historical origins and distribution of the earthen sites in Nile River Valley and the rammed earth Great Wall, summarizes the construction techniques and practices, and analyzes the challenges faced by traditional architecture and technology in the new era. Based on the common problems faced by current earthen sites, the adoption of China's methods might be considered. Traditional restoration methods offer a basis of valuable knowledge, but to deal with climate change and complex environments, more efficient scientific materials can be used to delay the development of wall decay. This study will enhance people's understanding of the two earthen sites and provide more ideas for the protection of the Great Wall and the structures in Nile Valley.

Keywords: Nile earthen sites; The Great Wall; Construction technology; Repair Method

INTRODUCTION

Just as the flourishing of the ancient civilizations of Egypt and the Sudan was dependent on the Nile, the Yellow River, known as the mother river of China, led to the development of the ancient Chinese civilization. In these widely-separated regions, people created a brilliant culture and made great contributions to the scientific and technological development of the world. This paper examines just one aspect of these civilizations: earthen architecture, considering the Great Wall of China in detail, with some comparison with the substantial mud-brick monuments of ancient Egypt.

1. LOCATION OF THE NILE SITE AND THE EARTHEN GREAT WALL

The Nile Valley starts from the East African Plateau in the south, reaches the Mediterranean coast in the north, extends to the Ethiopian Plateau in the east, and northwestward along the Red Sea, and borders the Congo Basin and Chad Basin in the west. The monumental remains of ancient civilizations along the river, however, are found in Egypt and the Sudan and include a vast array of earthen structures. The vast majority of these were constructed of sun-dried mud-brick, and they range from small domestic buildings to religious, military and administrative structures, as described in Spencer 1979. However, the buildings most relevant for comparison with the Great Wall of China are the massive mud-brick enclosure walls of temple complexes, the outer walls of the Nubian fortresses, and the funerary enclosures at Abydos and Hierakonpolis

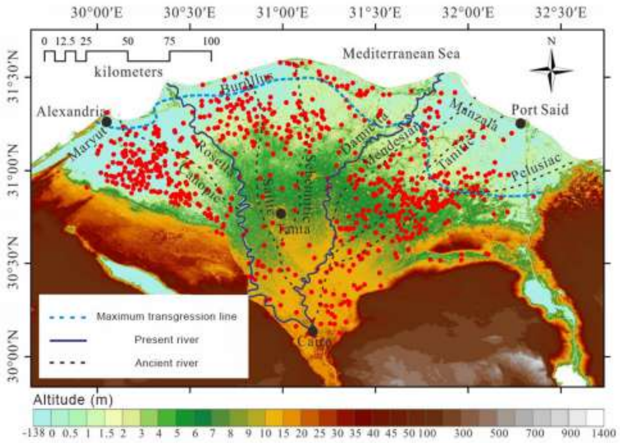

Figure 1: Distribution of sites in the Nile Delta.
© X.S. Zhao," Holocene climate change of the Nile River Basin and the response of early agriculture in its Delta", PhD Thesis, East China Normal University, 2020

(www.hierakonpolis-online.org/index.php/explore-the-fort). These monuments face similar problems of conservation and protection as the Great Wall.

The Yellow River originates from the Qinghai Tibet Plateau, flows through the Inner Mongolian Plateau, the Loess Plateau, the Huang Huai Hai Plain, and finally flows into the Bohai Sea. The Yellow River and the Great Wall run side by side in many places. According to the Chinese field investigation project of the Great Wall resources in 2008, earth material was widely used in the construction of the Great Wall, especially in northwest China, where the Great Wall is made almost entirely of earth. The Great Wall was built in every period, covering 12 historical dynasties such as Qin, Han, Tang, and Ming. Since the Great Wall's historical mission was to defend against ethnic minorities in the north, it is mainly distributed in northern China (Fig. 2).

In Beijing and Hebei, there are natural mountains that can resist foreign invasion, and natural stone is abundant, so mostly we see in these areas brick and stone walls. In the northwest of China, such as the vast grasslands of Inner Mongolia, the deserts of Gansu and the Gobi desert of Xinjiang, soil is the most common material, so the walls here are mostly made of earth. According to the information on the "Great Wall Heritage of China" website (http://www.greatwallheritage.cn/CCMCMS/), the length of the rammed earth Great Wall is the longest in all dynasties, accounting for more than half of the total length. And about a third of the total length is in Inner Mongolia, where the Great Wall is basically earth.

2. TRADITIONAL CONSTRUCTION METHODS

2.1 EARTHEN ARCHITECTURE IN THE NILE VALLEY

The use of mud-brick as a primary building material in Egypt began in the late Predynastic Period (c.3250 BC) and was still being employed for the construction of village houses in the 20th century. The manufacture of mud brick was the same in antiquity as in modern times. The murals from the tomb of Rekhmire in the ancient city of Thebes, at modern Luxor, painted around 1450 BC, show the entire process of ancient craftsmen using moulds to make bricks: first, water, clay, straw, and other raw materials are mixed and pressed into a wooden open mould placed on the ground. The excess clay on the top is scraped off and the bricks are tipped out and laid out in the sun for drying, The addition of additives such as straw and sand will make the clay less prone to cracking during exposure to sunlight. The production method of the mud brick is similar to the production method of adobe for the Great Wall. Of all the buildings created in Egypt and Sudan over this long period, the most substantial structures occur between the Middle Kingdom and the Ptolemaic Period. It was in the Middle Kingdom that a series of mud-brick fortresses were built in Nubia, to be repaired and enlarged in the New Kingdom (Somers Clarke 1930/1990). The outer walls of these were built as massive structures, with buttresses attached at regular

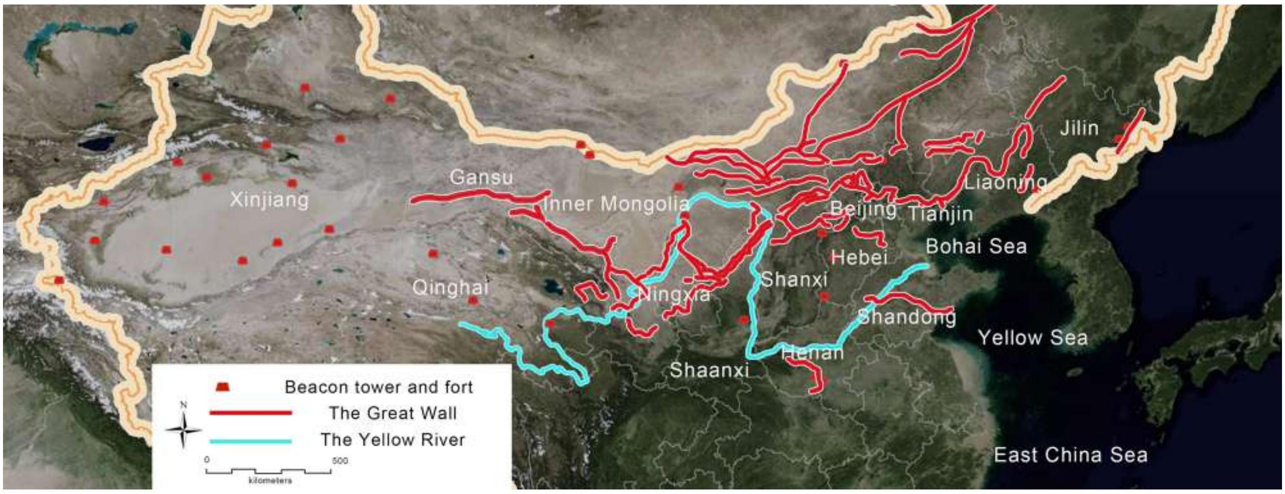

Figure 2: Distribution of The Great Wall.
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intervals. The design of these fortresses was very sophisticated, with double walls, ditches between walls, and defensive high gates, but it is the main outer walls that are the closest parallels to the Great Wall in China. In the New Kingdom, and more especially in the Late Period to Ptolemaic Period, even more massive mud-brick walls were constructed as enclosures for temples, these often being up to 20 metres thick. Such a thick mass of mud-brick is subject to similar decay issues to those found in the Great Wall, or any structure of similar scale and material.

2.2 EARTHEN TECHNOLOGY OF THE GREAT WALL

Like ancient Egypt, the Great Wall of China is mainly made of bricks, stones, and earth. In the process technology of soil materials, the most prominent ones are the rammed earth masonry technology and adobe, and rammed earth technology and adobe coexist, which are two systems developed side by side in Chinese geotechnical technology (Q.J.Wang 2007). There are three main construction methods for the existing earthen Great Wall: the most common one is the rammed wall, and in some areas, sand, gravel, red willows, and reeds are added to the loess to serve as a tie and reinforcement. The second method is to build the wall with adobe made of clay. And the third way to build the Earth Wall is directly piled up with earth.

2.2.1 RAMMED EARTH GREAT WALL

Ramming is the basic method used in the construction of the existing Earth Great Wall, and it appears in every period. The main characteristic of ramming construction is to use of local loess as the main material of the Great Wall. Ramming technology mainly depends on stone or iron tools, including wooden plywood moulds, pestles, rammers, and crutches. In China, the development of rammed earth wall technology appeared early. There are signs in the remains of the Yangshao culture more than 5,000 years ago (Xue 2018). The board frame technique had matured during the Spring and Autumn and Warring States periods, the description of building walls and embankments in the "*Zhou Li Kao Gong Ji*" involves the basic process, indicating that the board frame technique at that time was mature. Splints and ropes used for tamping have also been found in some well-preserved sites. According to historical records, the construction of the rammed-earth Great Wall required first digging trenches in the ground and burying foundation stones, then setting up wooden moulds around the foundation stones and fixing the moulds with ropes. Then, natural undisturbed soil or selected sand and gravel materials were added to the wooden board mould, and compacted with a rammer. The walls of the Great Wall are 8 to 10 meters high. Yongding columns were embedded in the rammed earth to defend against wind. Some walls have hard drainage surfaces at the top, which are formed with sand, lime, and stone. According to the survey results, a large number of rammed earth Great Walls are distributed in plains, hills, plateaus, and other relatively flat areas. In some areas located in the desert, the soil contains too much sand, which can affect the cohesion of the wall. In these areas, plant branches or grass reinforcement structures are often added to the Great Wall (Fig. 3).

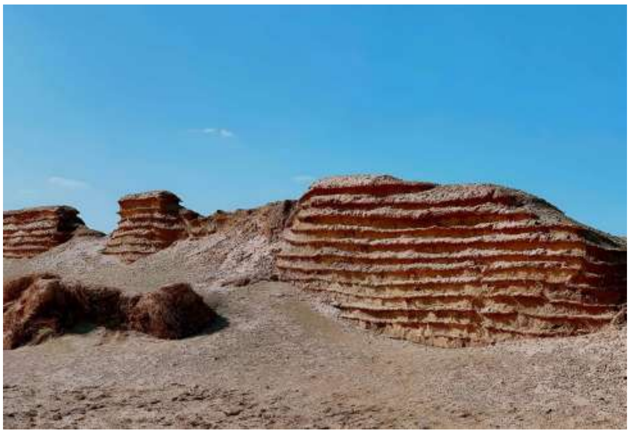

Figure 3: Great Wall of the Han Dynasty.
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2.2.2 ADOBE GREAT WALL

According to archaeological data, the site of Longshan culture in Pingliangtai, Huaiyang, Henan Province, has been identified as an early site for building walls with adobe (HCRRI 1983). Adobe brick technology meets people's needs for flexible construction, but it accounts for a small proportion of the construction of the Great Wall. The Great Wall of adobe bricks is mainly distributed in the Hexi region. According to Xue Cheng's research, there are beacon towers built with mud bricks in the Hexi region. The Great Wall of adobe mainly relies on skills: there are two ways to make mud bricks. One is to make an adobe by mixing earth and water into mud, cutting the semi-dry adobe into a uniform brick size. Another method is to put soil into the mould for ramming, compacting, and demoulding to form bricks. At present, no ancient moulds for making the Great Wall adobe have been found, but based on the size of the adobe bricks, it can be seen that there was no unified size.

2.2.3 STACKING EARTH GREAT WALL

Although most of the earth Great Wall in China was built with rammed earth, there are also a small number of walls that were directly formed by stacking soil and constructed by stacking techniques. In prehistoric times, stacking earth technology mainly appeared in the Yangtze River Basin of China. The climate there is humid, with a lot of rainfall and high soil moisture, mostly consisting of cohesive soil which is poor plasticity and unsuitable for using plate building techniques (Zhao 2002). Therefore, stacking technology was still popular in the Yangtze River Basin in the Shang and Zhou Dynasties.

Stacking technology is simpler than ramming technology and has lower requirements for the construction of wall foundations and materials. The cross-section of the stacked wall is usually wide (3-9 meters), and the accumulated soil is fixed by simple tapping, then it is more like a continuous soil slope. Some of the Qin Great Walls in Shaanxi and Gansu provinces used stacking technology, and most of them have been seriously damaged (Fig. 4). This type of wall is gradually disappearing (Ma 2012).

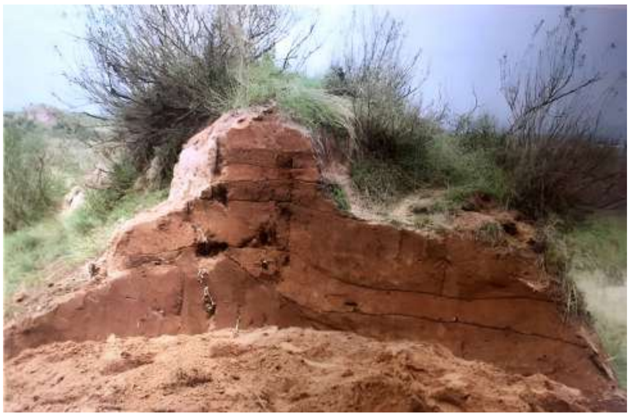

Figure 4: Stacking Earth Great Wall.
© C. Xue, "Research on Construction Technology of the Great Wall in China", PhD Thesis, Northwestern University, 2018

3. CHALLENGES FACED BY EARTHEN HERITAGE

Natural environmental changes and climate issues are the challenges faced by earthen sites. The figure 5 below shows people destroying the Great Wall to pass through, and figure 6 shows people forced to live in tombs. Rapid transportation and urban expansion development have changed the original environment of heritage sites. Earthen heritages face the problem of how to coexist harmoniously with modern cities.

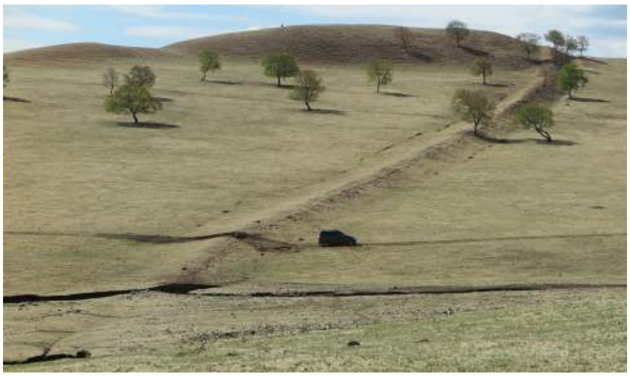

Figure 5: Artificial excavation.
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In addition, the bigger threat is climate. There has been a significant increase in rainfall in northern China. In July 2022, four of the six regional rainstorms in China occurred in the north. But in history, the northern part of China has always been dry. While the precipitation in the north increased, southern China experienced severe drought in 2022 after two consecutive years of super-strong plum rains. It can be seen that climate evolution will be complicated in the future.

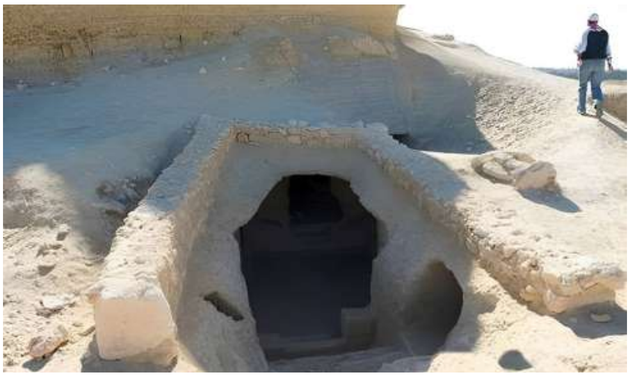

Figure 6: Living on an ancient tomb.
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Frequent extreme weather has become an undisputed fact. Severe extreme weather can disrupt the balance of the preservation environment of the site, accelerate its deterioration, cause greater damage and may have a devastating impact on fragile sites. The frequent occurrence of severe extreme weather and sudden disasters has once again sounded the alarm for the protection of cultural heritage. We are facing new challenges. This requires us to understand the causes of decay in earthen sites as soon as possible and find appropriate prevention and repair methods.

4. DISEASE AND REPAIR METHODS

4.1 CLASSIFICATION OF DISEASES

Soil is the main component of earthen sites, often used for construction due to being easy to obtain. However, there are a large number of voids in the loose soil structure, which makes it easy to produce deformation cracks and collapse due to the lack of flexural and shear resistance after geological disasters. At the same time, the physical and chemical properties of the soil change after encountering water, which seriously affected the stability of site structure. In addition, sunshine, temperature changes, biological erosion, and other environmental factors lead to earth deterioration. Through a lot of investigation and research, Xudong Wang, Zuixiong Li and other scholars classified the decay types present in earthen sites in China, and divided them into natural factors and human factors. According to the formation mechanism of the decay, the types of natural damage were divided into five categories, spalling, excavation, fissure, gully, and biological damage (X.D.Wang 2013).

4.2 HISTORICAL REPAIR METHODS

Almost every dynasty built and repaired the Great Wall. After Emperor Qin Shihuang unified the six states, he renovated the earthen walls of the Western Zhou Dynasty to resist harassment from border ethnic minorities. At the beginning of the Han Dynasty, the northern minorities disturbed the Central Plains. Under new military demands, the Great Wall of the Han Dynasty stretched into the Hexi Corridor and the western desert. It was still constructed by the traditional method of interleaved stacked stone pieces or rammed earth, but also by mud bricks. When ramming in the desert, craftsmen combined regional characteristics to develop the method of adding reed and red willow branches to the soil. After the Han Dynasty, with the improvement of production, brick and stone buildings gradually increased. During the Northern Qi Dynasty (AD 550-577), craftsmen at that time had already used lime as a binder to build the Great Wall.

The construction method of the Ming Great Wall is more flexible and scientific, reaching the peak of China's construction of the Great Wall in terms of technology and form. During the Ming Dynasty, craftsmen excavated a large amount of clay minerals, a large number of brick and tile kilns were built near the Great Wall, and the skill of making bricks and tiles is more mature. The use of traditional reinforcement materials for the Ming Dynasty Great Wall was more meticulous. It has a certain ratio of sand, coal slag, and crushed stone, and a large amount of glutinous rice mortar added. These make the Ming Great Wall very sturdy.

4.3 MODERN REPAIR METHODS

4.3.1 SPALLING

Spalling is a common decay type on earth walls. The soil particles that were originally bonded together had weakened cohesion, increased spacing, and deteriorated mechanical properties, leading to a loose and brittle surface of the site; the surface peels off in a honeycomb or cracked unevenness. For the flake denudation of rammed walls, the current conventional method is to clean the surface of the earthen wall and the modified raw soil material is rammed onto the denudated earth wall.

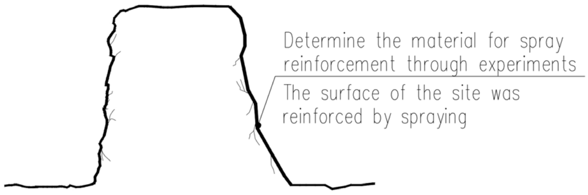
Determine the material for spray reinforcement through experiments
The surface of the site was reinforced by spraying

Figure 7: Reinforcement of the Spalling Wall Surface.
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It is not uncommon to use chemical reinforcement agents. The Dunhuang Research Institute has done a lot of experiments on chemical reinforcement. They used a combination of surface infiltration and pinhole injection infiltration to penetrate a 3% -5% concentration of high modulus potassium silicate (PS) solution onto the weathered wall surface (Fig. 7). Based on laboratory and field experiments, Zuixiong Li found that the use of PS reinforcement solution has achieved good results on several earthen sites such as Pochengzi Site of Han Dynasty in Anxi County, Gansu Province and Jiaohe Site of Turpan in Northwest China. Consolidants have also been used in Egypt, for example at Karanis, where brick and plaster has been reinforced by the application of cyclododecane (Wendrich *et al.* 2016).

4.3.2 EROSION

The erosion of rammed earth walls is common and typical, mostly caused by wind and sand. It mainly acts on the foundation of the site, showing concave erosion pits at the bottom. Exactly the same erosion at the base of walls occurs in the Nile Valley (Spencer 1994, 315-320). This decay phenomenon mainly includes: crisp alkali, wind erosion, flowing water erosion, freeze-thaw erosion, and collapse erosion (Li 1995). In response to erosion, the method of supporting the top of the wall is often based on the consideration of structural safety. The common method is to use adobe bricks to fill the concave area to form support for the top (Fig. 8). Erosion damage is also common on major Nile Valley monuments, such as the brick enclosures at Abydos and Hierakonpolis. The same technique of repair was employed, adding new bricks to support vulnerable areas of the structure. The modern bricks were all marked to distinguish them from the ancient masonry. To further aid stability, the brick courses were reinforced periodically with a special thin perforated sheet of plastic textile material (Crosby and Remsen 2002). This geogrid textile provides horizontal reinforcement in the new construction, for which the original builders used layers of reeds (Adams and O'Connor 2010; O'Connor *et al.* 2010; Jaeschke and Friedman 2011).

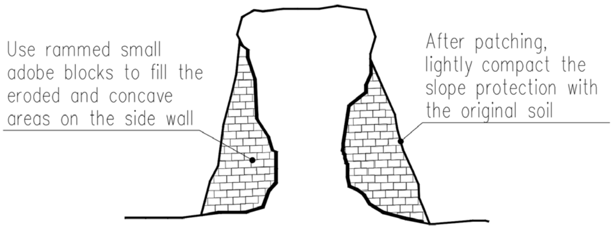
Use rammed small adobe blocks to fill the eroded and concave areas on the side wall
After patching, lightly compact the slope protection with the original soil

Figure 8: Reinforcement of the concave erosion Wall.
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4.3.3 CRACKS AND COLLAPSES

Cracks and collapses are serious types of decay, and wall cracking is the early manifestation of collapse. The main reason for the formation of cracks or collapses is the uneven distribution of wall stress, which accelerates the development of cracks and may lead to more serious consequences such as collapse. For earth wall fissures, grouting repair methods are commonly used now.

Pressure grouting is suitable for small cracks. For larger cracks, although grouting is also necessary, it is often used in conjunction with anchor rods. Before grouting, mud blocks or adobe bricks are usually used to fill the cracks. Filling the earth blocks can increase the overall stability of the wall, and then wooden ties are buried on both sides of the cracks (Fig. 9). By comparision in Egypt, deterioration of the great enclosure wall of the temple of Dendera was remedied by the insertion of new mud bricks to replace the collapsed sections (Vanpeene 2022, section 1).

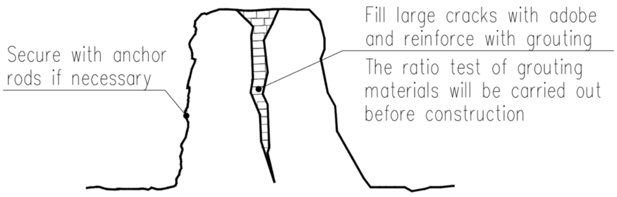
Secure with anchor rods if necessary
Fill large cracks with adobe and reinforce with grouting
The ratio test of grouting materials will be carried out before construction

Figure 9: Reinforcement of the Cracked Wall.
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Due to the distinct conditions in different places, the ratio test of grouting materials is carried out before construction. The result of the trial in the arid areas of northern China is that the mixing of high modulus Potassium silicate with fly ash and silt (PS-C+F) is an excellent material for grouting and reinforcement of earthen walls. The concentration of PS solution is 5%, and the ratio of the solution to the total silt and ash is 0.4 to 0.5 (H.Y. Zhao 2007). The material (PS-C+F) has been used in Guangchangsui, which is located in the desert area of Dunhuang City, Gansu Province.

4.3.4 GULLY

In geology, gully is a common landform in hills and valleys. Surface runoff erodes the wall, manifested in erosion ditches on the surface of the wall. Gully is the largest type of erosion ditch, with a length of several kilometers or tens of kilometers (S.Wang 2013). The basic remedy is to compact and fill the depressions on the site surface. Another type is caused by rainfall, when precipitation is heavy, it not only damages the surface, causing the wall to peel off, but also accumulates into streams of muddy water, eroding the soil mass. If the wall cracks, rain will seep down along the cracks at the top of the soil wall, expanding the width and depth of the cracks continuously, causing the wall cracks to form gullies. For this type of damage, it is necessary to provide waterproof protection after tamping the wall. Rainfall damage is also a factor in Egypt (Adams and O'Connor 2010, p. 5).

4.3.5 BIOLOGICAL DAMAGE

Earth walls are natural homes for animals, and they can provide the necessary conditions for plants to grow, so vegetation climbing and animals making holes are common in the walls. Similarly in Egypt, much damage was caused by hornets nesting in the brickwork (Adams and O'Connor 2010, 5). The accumulation of feaces from birds and other animals can cause surface pollution. The plant disease is always caused by the plant roots growing in the wall, which leads the wall to expand and bulge, causing hidden dangers that threaten stability. There are many methods for treating biological diseases now. For the unevenness and holes left by animal activities, most of them are directly filled and compacted to reduce the impact on the wall structure. To deal with plant damage, the traditional way is to clean up the trees and remove the roots and seeds. Modern chemical agents provide more options for weeding and sterilization.

4.5 CHINESE CASE

For the restoration of the earth's Great Wall, Yumen Pass will be discussed as an example. Yumen Pass was a pass built in the Western Han Dynasty. Materials were taken locally, the wall is built with clay, sand and stone. It is 24 m long from east to west, 26.4 m wide from north to south, 9.7 m high and it covers 633 square meters. The main decay factors of the Yumen Pass site are cracks, collapse, excavation erosion and gully.

The density of rammed earth in the wall of Yumen Pass is high, and the weathering degree of the wall surface is slight. Therefore, low concentration (2%~3%) PS is used to repeatedly spray infiltration reinforcement. For the collapsed wall, the wall was re-tamped. Grass was buried in each layer of rammed earth to increase the adhesion of rammed earth. Select a silty clay with little soluble salt, and mix 1/10 of the lime after the soil is dry and humid. After tamping, punched holes in the wall, and the wooden pole was anchored in the hole. Generally, the bolt above 2 m uses a steel and wood structure, and the bolt less than 2 m uses wooden bolts. The procedure of bolt anchoring is: drill the hole first, clean the soil in the hole after drilling, and inject PS solution to strengthen the hole. To make the new wall stable, a brick foundation (about 25 m long, 0.5 cm wide and 40 cm high) was dug along the original wall to solve the problem of slippage. As for the cracks, all cracks (inner and outer walls, top surfaces, etc.) were sealed by grouting. The large cracks are closed first, then filled with soil blocks, and after that injected with PS-F or PS+ clay slurry to achieve a better reinforcement effect. In order to make the top drainage of Yumen Pass no longer run over the wall, a PVC drain pipe with a diameter of 120 mm was buried in the flushing trench of the original wall to remove the water catchment at the top of the wall.

In a word, the wall that was cracked and in danger of collapse has been stabilized by tamping, anchoring and crack grouting, and the wall has been sprayed with PS penetration reinforcement, which has greatly enhanced the performance of the wall against wind and rain erosion.

CONCLUSIONS AND SUGGESTIONS

This paper compares the similarities between the Earthen Great Wall site and the Nile site. Gansu, Qinghai, Ningxia, Xinjiang and other western provinces have a dry climate, strong sunshine, large temperature difference, frequent sandstorms, little rainfall. The climate in Egypt is also dry, but the temperature is higher. Under the alternation of hot and cold, dry and wet, the earth structure becomes loosened, resulting in weathering, foundation erosion, cracks, gully and other decay. Through China's practice, there is a mature protection scheme for the earthen Great Wall in arid areas. The physical and chemical reinforcement methods have been successfully applied to multiple silt rammed or masonry sites in arid areas of northwest China, such as Jiaohe Ancient City and Guangchang Sui. These reinforcement materials have thermal stability and have potential in addressing the restoration of mud brick buildings in Egypt, and comparison of alternative treatments between the two areas will be of value.

At present, scholars are still researching new materials for different climate types and site decay. There is no doubt about that with the development and application of new materials, the continuous progress of new technology, the deepening of public participation, and the improvement of public understanding, the protection of earthen sites in the new era will have great prospects.

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DOCUMENTING EARTHEN CONSTRUCTION PROCESSES AND TECHNIQUES. CASE STUDY OF KSAR TIMIMOUN, ALGERIA

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SUMMARY

In the Sahara, earthen architecture illustrated, for a long time, a cultural heritage well adapted to the hot and arid climate characterizing this context. However, this architectural heritage is still experiencing accelerated abandonment and consequent deterioration due to contemporary socio-cultural and economic challenges, mainly climate change as well as the lack of procedures regulating the use of earthen materials. This study aims to contribute to the safeguarding of know-how related to the earthen architecture by means of constituting a documentation structuring the different stages to be adopted in order to preserve and reuse the traditional construction processes and techniques; a focus is made on the case of the Ksar of Timimoun, Algeria. This research work has been elaborated following two succeeding stages: i) exploring Timimoun city context as well as defining guidelines for the fieldwork, and ii) interviewing local known master earth builders in addition to undertaking in situ observations. The outcomes of this investigation consist of appropriate strategies for earthen architecture that emphasise on: i) organisation and work steps, ii) building material preparation, iii) construction processes, and iv) repairing and maintenance techniques. Even if these findings are particularly related to Timimoun city context, the methodological framework presented and here applied possess more wider implications. Its adaptation ability allows it to be a flexible operational tool for the documentation and sustainable conservation of earthen architecture throughout various contexts.

INTRODUCTION

Architecture serves as a tangible manifestation of societal values and environmental adaptability. Traditional settlements in Algeria testify it and portray an adeptness to confront the Sahara challenging climate. Due to its administrative promotions in 1974 and 2019, a significant historical centre in the Algerian Sahara, namely Timimoun, experienced considerable changes. In such a way, the gradual urbanisation impacted its traditional urban fabric and also altered the building materials' use from those locally-sourced to different industrial ones; hence disrupting the continuity of building cultures. Addressing these problems requires both understanding and documenting the earthen building processes. This research investigates the traditional construction techniques specific to the Ksar[1] of Timimoun (قصر تيميمون), emphasising and highlighting their cultural and chronological significance. By means of detailed documentation and field work recommendations, this research aims to intensively enhance the preservation of this region's cultural heritage, with potential implications for similar situations worldwide.

1. CONTEXT OF THE STUDY

Located in the heart of the Algerian desert, Timimoun city is culturally significant and environmentally characterised by a hot and arid desert climate. It is a part of the Gourara (قورارة)

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[1] *Ksar* (قصر), pl. *Ksour* (قصور), a typology of a traditional urban settlement well spread in north African countries see: Bisson 1999 ; Mahrour 2011.

region, surrounded by geographical landmarks like the Grand Erg Occidental to the north, Touat (توات) and Saoura (ساورة) regions to the southwest as well as Tademaït (تادمايت) plateau to the southeast (Fig. 1).

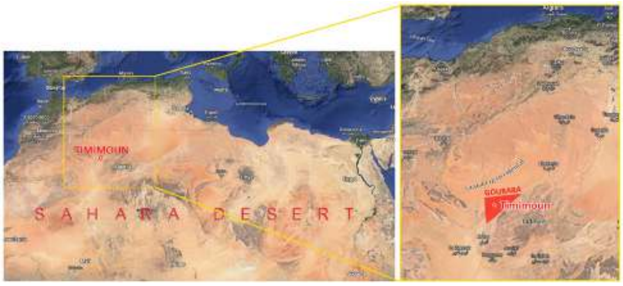

Figure 1: Situation of Timimoun city and the Gourara region in the Sahara desert.
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Timimoun knew a rich historical urban development that could be summarised in three main stages (Fig. 2) : 1) former citadels, namely Kasbat (or Aghem)[2], interrelated by a market in the 15th century[3] ; 2) a French colonial rural establishment at the beginning of the 20th century, including public buildings constructed with earthen materials and local building techniques, and 3) an urban expansion dating from the post-independence era, oriented towards the southwest areas as well as dominated by standardised home' models and faster executed social housing programs (Fig. 2). These recent interventions have created an imbalance in the architectural and urban expression of Timimoun, leading to the disruption of its traditional fabric and the irrigation network (Foggara, فقارة), that impacts the survival of the palm grove, a vital element of the oases system[4].

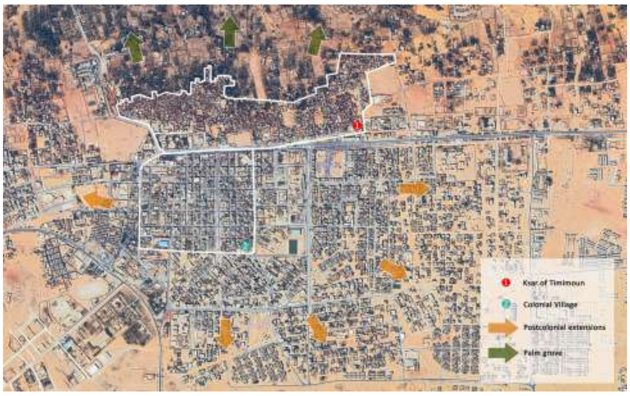

Figure 2: The urban development of Timimoun city: three distinct urban fabrics of three different historical eras.
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2. LITERATURE REVIEW

Due to their cultural importance, technical attributes, and potential contributions to sustainable development, a significant attention has been paid to the study of vernacular earthen building techniques and practices. This literature review extracts, among different studies from several fields of research, specific examples aimed at understanding the knowledge necessary for the use of local materials, their technical aspects and their cultural relevance. In addition, these case studies will allow the construction of this research's methodology.

2.1. ARCHAEOLOGICAL INVESTIGATION

In the semi-desert region of Jerid in southern Tunisia, Mrabet (2004) undertook an archaeological study of vernacular architecture and analysed the materials and construction techniques used for building. His study was focused on the following local elements of construction that he named "architectural techniques": 1) foundations, 2) walls, 3) roofs: ceiling and domes, 4) openings: arches, windows and doors, 5) stairs, 6) pillars, 7) water drains.

2.2. TRADITIONAL ARCHITECTURE STUDIES

Lebsir (2016) subdivided his study of vernacular architecture into three dimensions (cultural, technical, and patrimonial). Such knowledge structuring led to a deep global understanding of vernacular architecture. Besides, Zhao and Greenop (2016) emphasized four pillars of sustainability (cultural, social, economic, environmental) in vernacular construction. Using technical analysis and computational 3D modelling for reamed earthen buildings in Fujian (China), they developed a sustainable design model and guide.

2.3. CONSTRUCTION VULNERABILITY REDUCTION

Earthen buildings epitomise generational expertise and innovation that are fundamental for natural disaster resilience. Hence, the methodological framework developed by the "*Centre International de la Construction en Terre*" (CRAterre)[5] analyses building cultures in risk areas through participatory techniques, including drawing and interviews, fostering then disaster-resistant environments' both preservation and creation.

Overall, the reviewed literature highlights the significance of vernacular building techniques and practices for encouraging the existence of sustainable and resilient built environments. Insights from these studies lay the groundwork for our research methodology and fieldwork guide, focusing on earthen building techniques in southwest Algeria.

3. METHODOLOGY AND FIELD INVESTIGATION

Capitalising the outcomes of the previous literature review, the present research work categorized the construction techniques into two primary steps (Fig. 3): 1) the pre-construction phase encompassing organisation and material preparation, and 2) the construction phase including built activities and the maintenance of the building.

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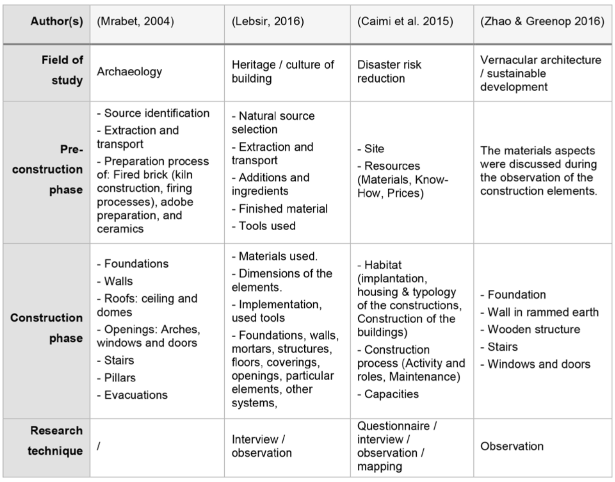
[2] The initial phase of the foundation of the Ksar, which consisted of one or group of familial or tribal settlements, generally fortified, named Kasbah, قصبة (pl. Kesbat, قصبات) or Aghem, آغام, see; Mahrour 2011.

[3] Bellil 2000

[4] Otmane, Kouzminee 2011, p.186, outline the oasis as traditionally consisting of the *Ksar*, palm grove, and *Foggara*. A degradation to one of these elements can impact the whole oasis system.

[5] Caimi 2014; Caimi *et al.* 2015



Author(s)	(Mrabet, 2004)	(Lebsir, 2016)	(Caimi et al. 2015)	(Zhao & Greenop 2016)
Field of study	Archaeology	Heritage / culture of building	Disaster risk reduction	Vernacular architecture / sustainable development
Pre-construction phase	- Source identification - Extraction and transport - Preparation process of: Fired brick (kiln construction, firing processes), adobe preparation, and ceramics	- Natural source selection - Extraction and transport - Additions and ingredients - Finished material - Tools used	- Site - Resources (Materials, Know-How, Prices)	The materials aspects were discussed during the observation of the construction elements.
Construction phase	- Foundations - Walls - Roofs: ceiling and domes - Openings: Arches, windows and doors - Stairs - Pillars - Evacuations	- Materials used. - Dimensions of the elements. - Implementation, used tools - Foundations, walls, mortars, structures, floors, coverings, openings, particular elements, other systems,	- Habitat (implantation, housing & typology of the constructions, Construction of the buildings) - Construction process (Activity and roles, Maintenance) - Capacities	- Foundation - Wall in rammed earth - Wooden structure - Stairs - Windows and doors
Research technique	/	Interview / observation	Questionnaire / interview / observation / mapping	Observation

Figure 3: Synthesis of literature review related to the documentation of the earthen construction techniques.
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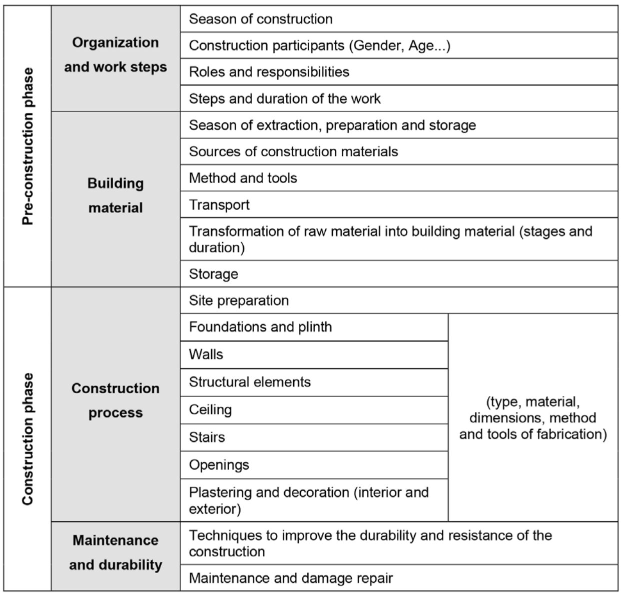
In addition, this literature review allowed the identification of the key points for both pre-construction and construction stages. Moreover, it revealed that the concerned authors structured their analyses and methods in respect of specific goals and context. Consequently, the pre-construction phase has been ordered into two succeeding steps (Fig. 4): 1) Organisation and work steps, and 2) building material. Similarly, the construction phase was subdivided as follows: 1) construction process and 2) maintenance and durability. Such revisited classification is fundamental to elaborate a comprehensive documentation model for the earthen building technique as it is aimed by the present research work.



Pre-construction phase	**Organization and work steps**	Season of construction	
		Construction participants (Gender, Age...)	
		Roles and responsibilities	
		Steps and duration of the work	
	Building material	Season of extraction, preparation and storage	
		Sources of construction materials	
		Method and tools	
		Transport	
		Transformation of raw material into building material (stages and duration)	
		Storage	
Construction phase	**Construction process**	Site preparation	
		Foundations and plinth	(type, material, dimensions, method and tools of fabrication)
		Walls	
		Structural elements	
		Ceiling	
		Stairs	
		Openings	
		Plastering and decoration (interior and exterior)	
	Maintenance and durability	Techniques to improve the durability and resistance of the construction	
		Maintenance and damage repair	

Figure 4: Adopted documentation model for earthen building techniques.
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3.1. CONDUCTING THE FIELD INVESTIGATION.

Hence, three “master builders”[6], aged over 50 years, have been selected to participate in the survey and suggest various future perspectives. Two were chosen among those listed by the “Centre Algérien du Patrimoine Culturel Bâti en Terre” (CAP-TERRE) whilst a third one which has been recommended by the local community. During the interviews with the master builders, the research objectives were explained and a positive relationship has been established with them. For more feasibility, the questions were expressed in Arabic. Complementary observations were done using measurements and photographs to support the results of our interviews. This allowed to gather in-depth information from multiple sources for accuracy and reliability.

4. RESULTS AND DISCUSSION

4.1. ORGANISATION AND WORK STEPS

In Timimoun, the traditional construction process comprises design, material preparation, and construction activities. Building materials are mainly prepared during spring, using available natural fibres. Construction activities are mostly achieved during temperate times to avoid mortar drying problems in summer.

The construction’s different tasks are attributed in respect to experience, age, and gender. The work team includes specialists like carpenters for roof construction, ranging from young apprentices to master builders. Women typically assist, e.g., by supplying water for materials’ mixtures. Two prevailing kinds of construction contracts exist in Timimoun: 1) an owner hiring a mason who leads a team for the construction, and 2) a communal endeavour, namely Twiza (تويزة), constituted of local inhabitants to build or repair a house and also to transport the building materials.

4.2. BUILDING MATERIAL

The traditional construction process in Timimoun uses various materials, including stone, adobe, and palm wood. Each material has its particular extraction mode and preparation process, as well as specific methods for storage.

4.2.1. STONE

In the Gourara region, the stone is mainly used for building bases and foundations. Often sourced from Timimoun and the nearby Ksour, this stone doesn’t need specialised tools for extraction.

A type of sandstone, locally called Tafza (تافزة), is known for its high porosity. It is used both as foundational support but also as an external protection of the wall and hence contribut-

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[6] Karakul 2015

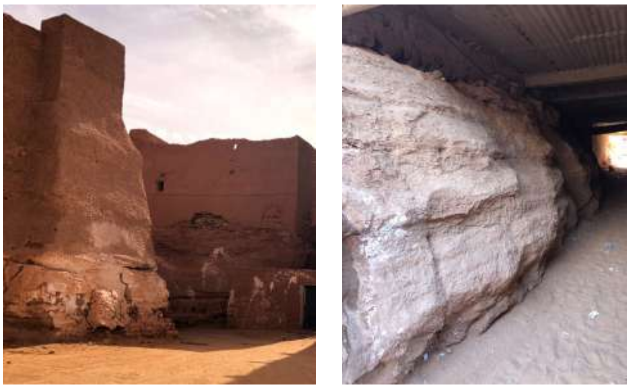

Figure 5: Tafza stone as a support of old building in the Ksar of Timimoun.
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ing to the internal thermal regulation. Its adoption decreased during the colonial era with the introduction of lime.

4.2.2. ADOBE AND MORTARS

Adobe is the primary material for walls in the Ksar of Timimoun. The adobe mixture, more clayey than sandy, mixes topsoil locally called el-Bali (البالي) or Trab el-Miyet (تراب الميت) with the clay-rich, Trab el-Hai (تراب الحي), from the local clay deposit known as T'gazza (تقازة).

Three steps were identified for the adobe's production: 1) Preparation of the mixture: The ratio of *el-Bali* to *Trab el-Hai* varies in respect of its final use (Adobe, mortar, or as a screed for the floor or the roof). Mixed with water and natural fibres in a 2 x 2 m pit (Fig. 6), it's advisable to let the mixture settle for several days or even weeks, being stirred weekly. 2) Moulding: Common adobe dimensions are 30 x 15 x 15 cm and 35 x 15 x 15 cm. After sprinkling sand on the work surface and setting the mould, the mixture is projected, ensuring no voids. Depending on the season, adobes are rotated after a day or two for even drying. 3) Storage: Once sun-dried, adobes are stored shielded from rain, ensuring their quality for future use.

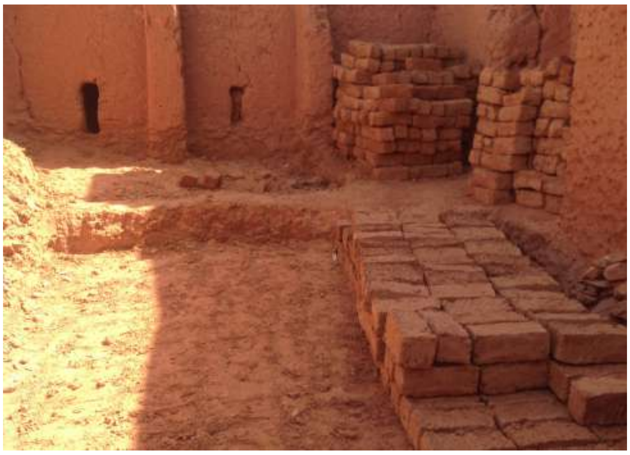

Figure 6: A pit for adobe preparation.
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4.2.3. PALM TREE WOOD

In Timimoun, local palm tree wood is essential for constructing ceilings, openings, and stairs. The tallest palm trees, challenging to climb for date collection, yield the most joists. After selecting a palm, it is cut, trimmed, and its trunk is segmented into lengths of 1.5-2.8 m according to the span, further divided into beams (Bghal, بغل) or joists (Khcheb,خشب) of 18-25 cm width.

Leaves (Djrid, جريد) from the palm tree are divided into three sections: 1) the base (Kernaf, كرناف); 2) the central portion (Assiy, عصي) after removing leaflets; and 3) the leafy upper segment (Saaf, سعف). These leaves are stored in a cool environment, only cut as needed.

The most suitable method for their storage is for the palm wood joists to be raised off the ground, thereby ensuring air circulation and therefore minimizing the risk of termites. They are kept elevated for at least three months before use.

4.3. CONSTRUCTION PROCESS

When the building materials have been acquired, the construction process begins with site preparation, including ground levelling and cleaning. The following construction steps are carried out in the specified order:

4.3.1. FOUNDATIONS AND PLINTH

Foundations play a crucial function in construction as they distribute the building loads to the ground. The foundation and plinth are built as a single element with the same material. Initially, a trench is dug around the house with a larger thickness than the foundation's one by 10-20 cm. The trench's depth varies in function of the soil type and generally does not exceed 50 cm in Timimoun. Stones are used for the foundation construction, built with the same bonding direction of the wall, joined with an earthen or lime mortar.

4.3.2. WALLS

After setting the foundation, the wall construction proceeds. The masonry bonding for these walls varies in function of their location (internal or external) and their load-bearing capability. Within the Ksar, the most prevailing bonding, namely Touba (طوبة), uses a single adobe (Fig. 7). However, for external walls, the Touba o'Noss (طوبة و نص) technique is preferred. It uses one and a half adobes. However, the single adobe (Touba) technique is widely preferred. It provides efficiency in the construction of load-bearing walls, minimum thickness and less building consuming duration.

The construction process begins at the wall limits. The master mason put down the adobes at the walls' angles. This makes it easier to continue laying out the rows by his assistants. It is a standard practice to maintain joints of 2-5 cm between the adobes, which are subsequently filled with earthen mortar. In the Ksar of Timimoun, walls usually don't surpass a height of 3 m without the need for horizontal chaining.

4.3.3. STRUCTURAL ELEMENTS

Two fundamental structural systems are frequently used alongside load-bearing adobe walls:

- The column-beam system is mainly used for supporting roofs without need of load-bearing walls. The columns in this configuration are predominantly made of adobe or an entire palm trunk. Despite their availability, palm trunk columns are not so popularly chosen due to their vulnerability to termite. The process of building earthen columns requires a careful arrangement dependent on the dimensions of the section (Fig. 7). Palm wood beams are commonly used as horizontal supporting elements. They are used by cutting the trunk in two or assembling several joists according to their spans and load. Recently, metal beams have been introduced as a building material in Timimoun and have substituted the palm wood beams. Their use has changed the shape of the space by increasing the span and therefore its width and/or length.

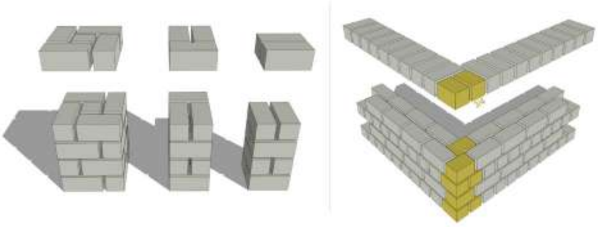

Figure 7: Types of adobe columns found in the Ksar of Timimoun (left). Masonry technique of one adobe/touba (right).
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- The other building system is constituted by arches, vaults, and domes; a set of strategies optimising space without modifying the nature of the construction materials of the adobe load-bearing walls. The Ksar of Timimoun features two distinct forms of arches: 1- a triangular geometric shape replaces the lintel in entrances and narrow corridors, and 2- a full arch shape with a greater width than the triangular shaped one. The latter is more prevalent in the colonial part of the city. The construction of arches is achieved by means of building elements such as adobes and joists as a support that could be recovered later (Fig. 8). Domed structures are not common in the case of residential buildings but are usually used in sacred buildings, particularly the tombs of saints. Timimoun's domes have a typical ogival shape with four distinct faces or walls.

Structural reinforcement elements such as buttresses characterize the buildings in Timimoun. They are mostly used to reinforce arch systems or walls under eccentric loads. The buttresses are implemented with the masonry of the element to allow proper transmission of loads.

4.3.4. CEILING AND STAIRS

When the wall construction is achieved, a final layer of flat stone is added to the top to support the joists. Following the drying of the mortars in this row, masons lay the joists as the first element of the ceiling. Due to the minimal multi-story constructions' number in the Ksar, most floors are terraces and accessible by stairs.

The spacing between joists ranges from 25-30 cm, with anchoring in the wall at 25-30 cm. When the mortar is dry, the masons pose the *Assiy* in a opposite sense to the joists, with a maximum spacing of 7 cm. Then, they apply a crossed layer of Djrid. When this last task is achieved, the masons continue constructing the wall, creating the top edge. A second-to-last layer of the ceiling consists of fibres called Bromi (برومي), enhancing waterproofing. Masons prefer to use the Bromi just before the last layer to prevent the fibres from being blown away due to their light weight.

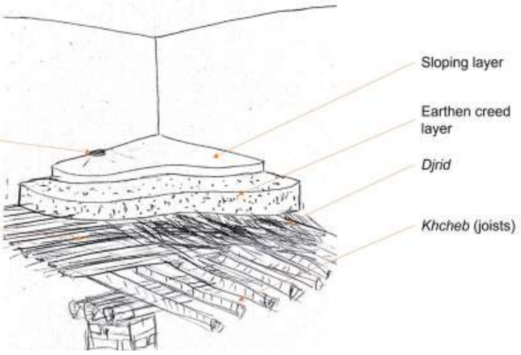

Figure 9: Ceiling system of the traditional construction building in the Ksar of Timimoun.
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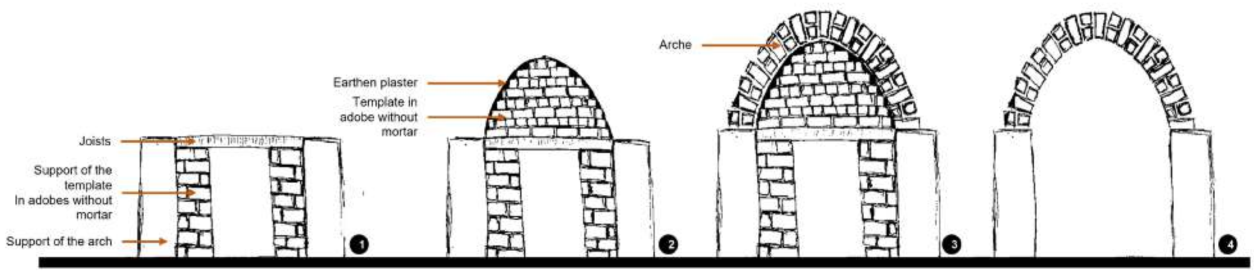
Arche
Earthen plaster
Template in adobe without mortar
Joists
Support of the template In adobes without mortar
Support of the arch
1
2
3
4

Figure 8: Traditional arches construction in the Ksar of Timimoun.
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The last part of the roof is screed which comprises two layers: 1) a 10 cm layer of earthen mortar, that is followed by: 2) a sloping final layer. This latter could be made of 5 cm of earth or less with lime. When this sloping layer is achieved, the masons introduce a weep hole (Mizeb, ميزاب) by creating holes in the roof walls.

In the Gourara region, traditional houses incorporate stairs as a fundamental element, typically positioned at the centre of the house and adjacent to the covered interior central space[7]. This location serves a dual purpose that is the provision of both private and semi-private access to the toilets (Takjemt, تاقجمة) that are usually located at the top of the staircase.

Two distinct types of staircase are commonly found in the *Ksar* of Timimoun. The first is monolithic, constructed from earth and featuring flat stone steps. To implement this type of staircase, the masons build a thick wall of 70-90 cm using adobe in degradation, which will give the shape of the steps. The second type of staircase is made of both adobe and palm wood and is the most prevalent in Timimoun. This design features a space underneath the staircase that is often used as a bread oven. To construct this type of staircase, the masons begin by building the first three steps using adobe, reserving a support to place joists or half palm tree trunks. Once the structure is in place, the steps of the staircase are constructed with adobe and covered with flat stones.

4.3.5. OPENINGS

The dimensions of the doors in the Ksar of Timimoun vary between 170-190 cm in height and 70-100 cm in width. The shutters are made of several flat wooden joists assembled by wooden boards. The exterior doors have a locking system integrated into the wall. The openings are not numerous on the envelope of the Ksar house and could be classified into three types: 1) the oldest one is a small slit or opening generally located at an important height of the room wall, 2) the vertical double-panel window, less higher than the first window type, providing a significant view to outside and introduced during the colonial period, and 3) a horizontal opening, namely Ain e-dar (عين الدار), located at the covered central courtyard's ceiling plane and providing a zenithal daylighting as well as ensuring natural ventilation.

4.3.6. PLASTERING AND DECORATION

In hot arid regions, wall plastering is essential for protection against rain, sand winds, and strong heat. In Timimoun, a local technique consists of using earthen balls that are projected by hand on the external face of the wall (Fig. 10). This wall surface shading technique called Lougma (لقمة) in other Saharan regions[8]. It has been done from the technical point of view by hand or using new tools like the trowel.

The oldest earthen plastering in Timimoun involves applying a earthen monolayer plaster to cover the joints between the adobes, using the same mortar as the one used for adobe production. For the interior of the house, two layers of plastering are successively applied: 1) a layer made with the same mortar as the adobes, and after drying, 2) a finishing plaster of a local type of clear colour clay or lime.

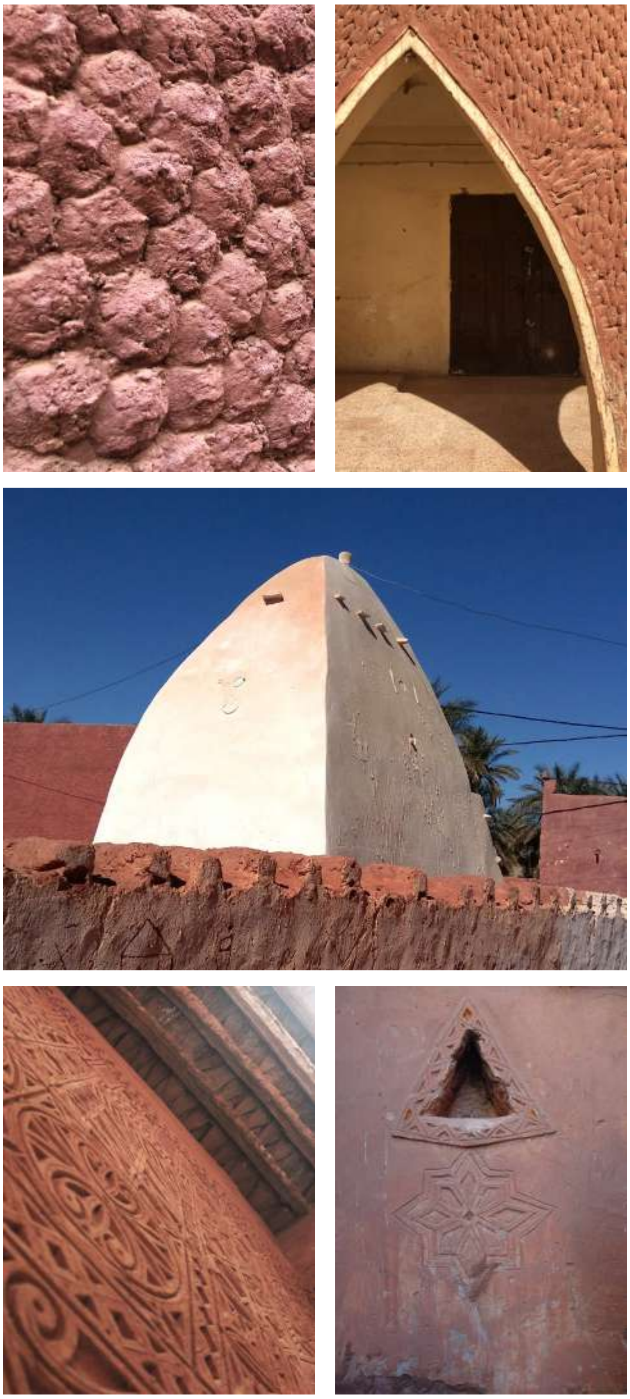

Figure 10: Exterior earthen and lime plastering (on top). Decoration techniques found in Timimoun (on bottom).
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[7] Bisson 1999

[8] Belakehal, Tabet Aoul 2000

In terms of decoration, such elements are not numerous in the Ksar. The decorations observed are sculpted on earthen plaster in a humid state and can be found framing entrance doors or as a decorative element with geometric forms inside the houses. However, this technique is more present in the colonial part of the city, as confirmed by our interviewees. The example of the current CAPTERRE headquarter, formerly known as "Hotel Oasis Rouge", built and decorated during the colonial period, seems to be its most illustrative.

4.4. MAINTENANCE AND DURABILITY

Providing longevity and working for the preservation of old buildings in the Ksar of Timimoun requires a deep understanding of the local construction techniques. So, this knowledge becomes more affordable through the various stages - from preparation to post-construction. In front to wall cracks, masons adopt two traditional repairing methods: 1) for the case of non-load bearing walls, olive tree branches are strategically placed perpendicular to the direction of the cracks, maintaining a consistent 20 cm spacing between each branch, and 2) for more deep cracks within load-bearing walls, a stronger solution is required e.g. the construction of a buttress that seamlessly merges with the masonry of the affected wall.

The external walls are constantly exposed to direct solar rays, rains and sandy winds as well as human impacts; a fact that requires regular repairing. Surface degradation is usually prevented thanks to periodic plastering. For deeper damages, the integration of stones associated with the earthen mortar consolidates the impacted areas. The ceilings, particularly the wood, are vulnerable to wood-eating pests such as termites locally called Arada (آرادة) or Timdi (تيمدي). To mitigate this, the stone supports for the joists are plastered with lime. Furthermore, sections that show damage receive a lime treatment or sometimes salty water. In especially severe cases, it becomes imperative to substitute the effected element with new, undamaged ones.

CONCLUSION

The documentation model of earthen construction technique applied for our case study has provided an invaluable opportunity for a large understanding of the use of natural resources in the traditional construction.

Our investigation allowed reconstructing the specifically traditional dimension from a methodical understanding of the use of the material and the rules of its art. The results of our work constitute a database documenting an ancestral know-how related to the production of what is today considered as a cultural heritage. Instead of accepting that this built heritage is devalued, more getting forgotten, as well as the fact that earthen constructions are neglected, we suggest that this research work should be a starting point for the development of earthen architecture and its related know-how.

The adopted methodological approach demonstrated the feasibility of constituting a documentation base focused on the use of earthen material in traditional construction. However, it must be underlined that further research is needed to broaden this research work perspectives to other dimensions of the constructive culture as well as to experiment and enlarge the analysis and investigation of traditional earthen construction techniques in other contexts.

In conclusion, we suggest that the lessons learned from our work in the Ksar of Timimoun be made available to experts working in the field. We also emphasise the importance of adopting a critical stance towards the methodological approach, as this will enable the identification of areas for improvement and the formulation of recommendations that will benefit the wider scientific community.

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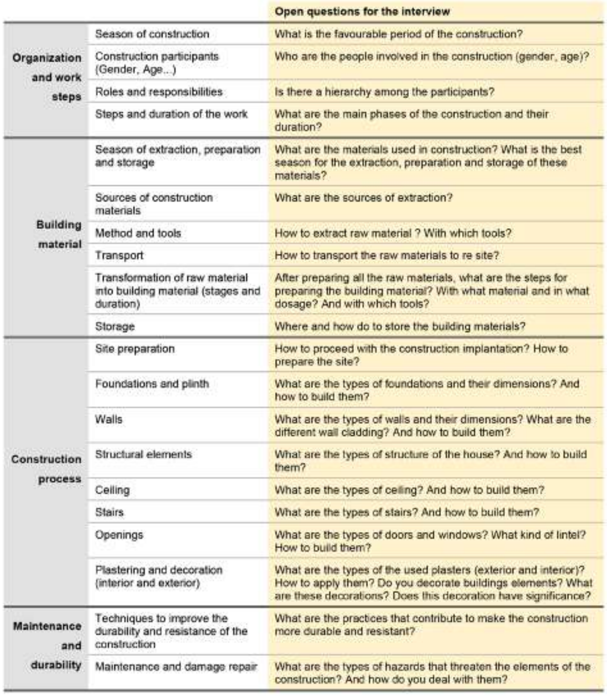
ANNEX



		Open questions for the interview
Organization and work steps	Season of construction	What is the favourable period of the construction?
	Construction participants (Gender, Age...)	Who are the people involved in the construction (gender, age)?
	Roles and responsibilities	Is there a hierarchy among the participants?
	Steps and duration of the work	What are the main phases of the construction and their duration?
Building material	Season of extraction, preparation and storage	What are the materials used in construction? What is the best season for the extraction, preparation and storage of these materials?
	Sources of construction materials	What are the sources of extraction?
	Method and tools	How to extract raw material ? With which tools?
	Transport	How to transport the raw materials to re site?
	Transformation of raw material into building material (stages and duration)	After preparing all the raw materials, what are the steps for preparing the building material? With what material and in what dosage? And with which tools?
	Storage	Where and how do to store the building materials?
Construction process	Site preparation	How to proceed with the construction implantation? How to prepare the site?
	Foundations and plinth	What are the types of foundations and their dimensions? And how to build them?
	Walls	What are the types of walls and their dimensions? What are the different wall cladding? And how to build them?
	Structural elements	What are the types of structure of the house? And how to build them?
	Ceiling	What are the types of ceiling? And how to build them?
	Stairs	What are the types of stairs? And how to build them?
	Openings	What are the types of doors and windows? What kind of lintel? How to build them?
	Plastering and decoration (interior and exterior)	What are the types of the used plasters (exterior and interior)? How to apply them? Do you decorate buildings elements? What are these decorations? Does this decoration have significance?
Maintenance and durability	Techniques to improve the durability and resistance of the construction	What are the practices that contribute to make the construction more durable and resistant?
	Maintenance and damage repair	What are the types of hazards that threaten the elements of the construction? And how do you deal with them?

Figure 11: Interview questions built based on the documentation model of earthen building techniques.

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SUB-THEME 1.1 - HISTORY OF EARTHEN ARCHITECTURE: ORIGINS, EVOLUTIONS, TECHNOLOGICAL BREAKTHROUGHS AND CONTINUITY

LAST TESTIMONIES OF EARTHEN ARCHITECTURE IN ORIGINAL COMMUNITIES OF TARAPACÁ, CHILE

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SUMMARY

The earthen architecture heritage in the Tarapacá region has developed over a long period of time. Despite the earthquakes and cultural transformations that have taken place over the last centuries, settlements dating back to more than two thousand years, as well as colonial buildings and houses, all built with earth are still preserved. However its historical, ecological and aesthetic importance, the use of this material has neither been sufficiently studied nor duly appreciated. Therefore, and as a part of a larger research comprising several sources of information, unpublished construction records and testimonies about the indigenous communities' know-how, this article aims to present part of the historical and cultural evolution of Tarapacá's vernacular architecture, mainly of earthen buildings, and also to rescue local cultural practices and construction techniques, which highlight the symbiosis between ecology in the territory and its traditional forms of social occupation, which are in turn associated with agricultural cycles and rituals of the Hispanic-Andean syncretism.

INTRODUCTION

The cases that are presented in this article are located in the area of indigenous development in the Tarapacá region, northern Chile, specifically in the Tarapacá, Aroma and Sotoca valleys (Fig. 1). It should be noted that the communities in this area are mainly of Aymara origin and, to a lesser extent Quechua, according to data provided by the Chilean Ministry of Social Development.

The cultural development of the Tarapacá territory has been documented well and is studied on a regular basis, mainly from the fields of sociology, anthropology, history and archaeology (Núñez 1966, 1979, 1984; Núñez 1983; Van Kessel 2003; Arriaza 2007; Gundermann, González 2009; Urbina *et al.* 2006, 2012, 2018; Adán *et al.* 2013; Zori, Urbina 2014). Scientific interest in the local architecture has focused on colonial architecture (Benavides, Vilaseca 1981) and the buildings and settlements of the saltpetre period (Garcés 1988; Aguirre 2004).

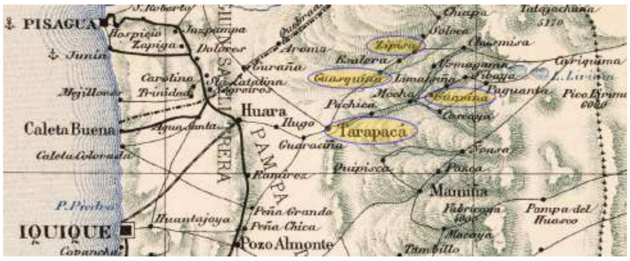

Figure 1: Province of Tarapacá from the Descriptive Geography of the Republic of Chile. Section of map with the Indigenous Communities of Huaviña, Huasquiña, Sipiza and Tarapacá highlighted.
© Enrique Espinoza, 1903 (David Rumsey Historical Map Collection) edit by J. Quiroz Bravo

In terms of State management, in 2003 the Ministry of Public Works first published the Aymara Architectural Design Guide (Ugarte, Rodríguez (eds.) 2003), which characterises the typologies representing the ways of living in the foothills (Fig.

2) and the Altiplano, with differentiated environmental and cultural traits. Similarly in 2013, the Ministry of Housing and Urban Planning published the Chilean Standard for Structures design – Retrofitting of historic earth buildings – Requirements for the structural design planning (NCh3332:2013). However, this standard came too late for the reconstruction of houses that were damaged by the 2005 earthquake (its epicentre being the town of Tarapacá) because, with few exceptions, neither the State nor the communities gave continuity to the traditional ways of building but, on the contrary, industrialised materials and house designs that are discordant with the local identity were introduced in the villages, leading to the irreversible loss of the indigenous communities' earthen architecture and cultural landscape.

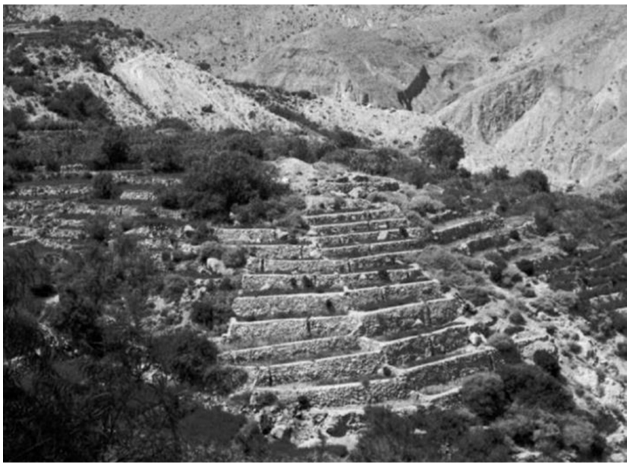

Figure 2: Andean terrace farming system. The Village of Limacsiña on Tarapacá Valley.
© Roberto Montandon, Chile, 1950 (Department of Architecture Photographic Archive)

1. PREHISPANIC ARCHITECTURE IN TARAPACÁ

Pre-Hispanic architecture in today's Tarapacá region has encouraged significant contribution from archaeology. The formative period[1] is of great interest due to the complexity of the emerging societies that developed here, thus representing the basis of the social organisation of the indigenous settlements that are the subject matter of this study. The evolution from archaic architecture to village formation is the result of a change in the production pattern, with the development of traditional Andean agricultural practices acting as a determining factor in the rise of new forms of house building. The cases analysis in the valleys of Tarapacá distinguishes the domestic sphere, the public building and the village layout, as axes of innovation in architecture and construction patterns (Urbina *et al.* 2012, 2018). Consequently, the agglutination of habitable units began in this period with the coexistence of circular, rectangular, quadrangular, ellipsoidal, trapezoidal and irregular architectural morphologies. The main building materials were mud mortar, adobe and stone. The village of Caserones in the Tarapacá valley, saw different periods of occupation, from 20 BC to 250 AD and from 780 to 1100 AD with quadrangular and rectangular enclosures, mostly agglutinated and surrounded by a perimeter wall to the south (Fig. 3). The walls have preserved their good resistance despite the passage of time and earthquakes in the area. They are made of masonry with irregular pieces based on anhydrite (calcium sulphate), also known as caliche, and have been joined with clay mortar and hydrated calcium sulphate, with inclusions of andesite and basalt type stones in the lower section of the walls. There were double course walls and, to a lesser extent, single course walls. The roofs feature a wooden structure (Núñez 1966). In the same area and of greater antiquity, lays the village of Pircas, which features a scattered pattern of isolated structures and a central compound with an agglutinated pattern that includes housing, services, ceremonial, cemetery and geoglyph structures. This central compound has more solid double-row walls and, in many cases, straight corners (Núñez 1984). The Ramaditas site, located a few kilometres from the Guatacondo valley, is considered the oldest village in the Tarapacá region and has enclosures with a scattered pattern featuring mainly curved walls and oval-shaped floors. The walls were built with wet mud mixed with andesite and basalt stones (Adán *et al.* 2013). Part of the techniques used in this village, in some enclosures with curved ground floors, can be defined as moulded earthen walls because mortar predominates with embedded isolated stones in rows spaced far apart.

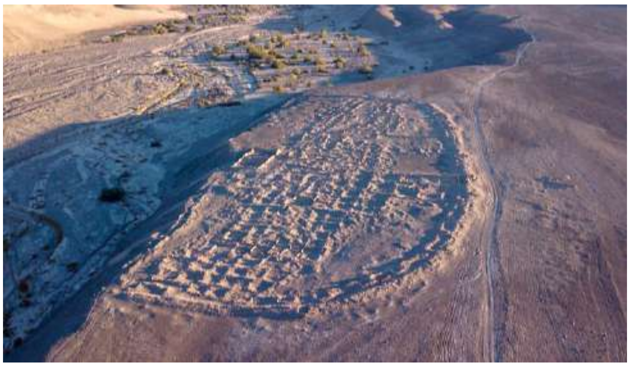

Figure 3: The Village of Caserones.
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2. ANTHROPOLOGIC RUPTURE IN THE INDIGENOUS OF TARAPACÁ

Although the extirpation of indigenous idolatry imposed during the colonial period between the 16th and 18th centuries led to today's prevailing cultural syncretism; after the republican independence processes at the beginning of the 19th century, the territory of Tarapacá was disputed by late the same century in the War of the Pacific between Peru, Bolivia and Chile due to the abundance of mineral resources, however the indigenous peoples and their culture did not represent a major interest for the incipient Republic of Chile, which managed to annex this region (Gundermann, González 2009). The rapid development of the saltpetre industry in the

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[1] The formative period in the region, spans from the 10th century BC to the 11th century AD.

19th century, roughly until 1930, entailed the construction of new settlements in the 'Pampa', with modern facilities such as post offices, schools, markets, theatres and swimming pools, thereby bringing these possibilities closer to the indigenous communities, which progressively migrated in search of the new. This resulted in extra labour for the mining industry, but also in the abandonment of their ancestral villages and agricultural role (Fig. 4). Historically marginalised, the indigenous people of Tarapacá have kept many traditional community practices in their villages to this day, such as the Ayni, the Wilancha, the Patron Saint Festivities, etc. (Van Kessel 2003). However, according to some testimonies, earth houses built following local traditions were still being erected until the end of the 1950s.

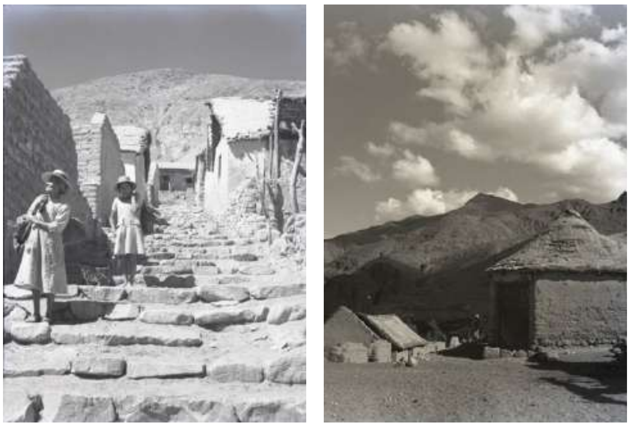

Figure 4: The indigenous towns of Mocha and Sibaya.
© Roberto Montandon, 1950 (Department of Architecture Photographic Archive)

Between the 1970s and 1980s, roads began to be built to allow access for many of the indigenous villages in the region. This also marked the massive influx of construction materials that were inconsistent with the vernacular culture. On the one hand, the indigenous communities no longer build in the traditional way, nor do they pass on their earthen architecture knowledge and, on the other hand, they distrust the resistance of these structures, considering these construction processes to require a great deal of effort, thereby assimilating modern aesthetics as an ideal of progress. Statistics show the evident process of migration from indigenous communities to the cities of this and other regions of Chile. Of the 40.934 Aymara registered in the region in 2002, 70.5% (28.654 people) live in urban centres, and the remaining 29.5% (12.280 people) dwell in rural areas (Arriaza 2007).

3. VERNACULAR ARCHITECTURE OF TARAPACÁ IN THE 21ST CENTURY

The loss of vernacular architecture and traditional earth-based construction systems as a result of the destruction of a large portion of the indigenous communities' built heritage - mainly due to the earthquakes that struck the region (recently in 1976, 1987, 2005 and 2014) - led to interventions lacking cultural identity, and in general lacking heritage conservation specialists, which began to be registered in the 1980s. However, it was after the 2005 earthquake that the loss of earthen architecture spread widely with the implementation of public policies encouraging the use of reinforced masonry, cement blocks, metal structure roofs with zinc plates[2] for the reconstruction of houses in indigenous villages. Similarly, the adaptation of urban construction models in traditional villages has resulted in the loss of construction practices and, consequently, also in the loss of the built heritage due to abandonment, wear and tear and poor maintenance. Today, in these villages it is possible to find a few cases of earth architecture in different states of preservation: community or public architecture such as altars, chapels, churches (Fig. 5); houses and ovens (Fig. 6); agricultural architecture such as irrigation canals, cultivation terraces and retaining walls; and also archaeological sites.

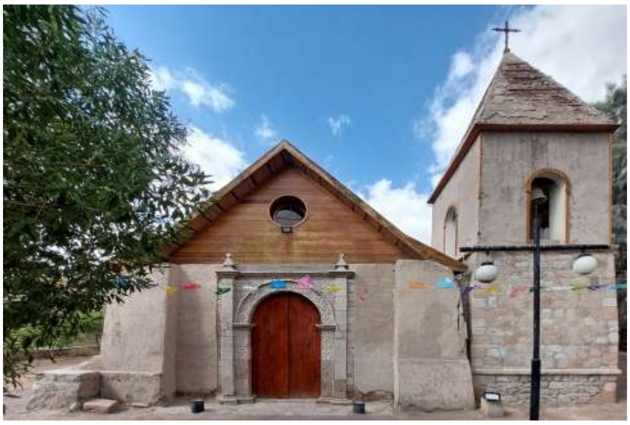

Figure 5: Colonial Andean Baroque Church in the village of Huaviña. Earthen architecture restored in 2010.
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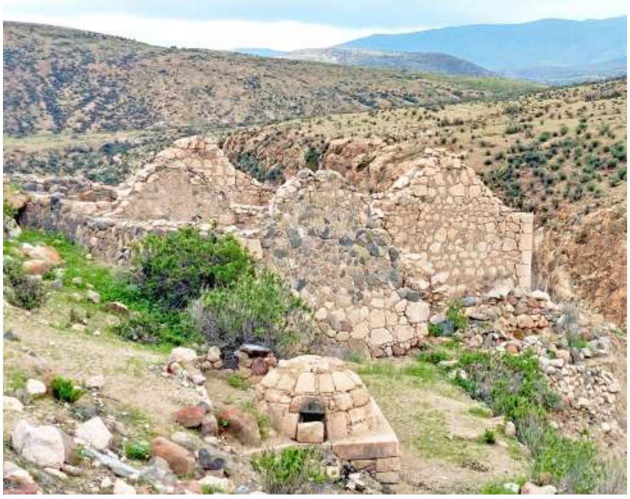

Figure 6: Houses and oven made of earth and stones.
Village of Sipiza.
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[2] According to the Ministry of Housing and Urban Planning's 2010 Management Report, following the 2005 Tarapacá earthquake, reconstruction was 82% complete to date, with 3.170 houses rebuilt.

3.1 THE HUAVIÑA COMMUNITY CASE

This community holds a great number of people living in the village and in addition to agricultural work, there is a school for young children. Among the buildings preserved in the village there is a residential typology, consisting of two identical buildings separated by a central corridor, which also serves as the main entrance (Fig. 7). Each building has a rectangular ground plan with a gabled roof and a stone basement varying in height from half to a metre depending on the slope of the terrain, on top of which lays an adobe masonry with head rigging, all set in mud. Each pediment at its upper end moves inward. The longest walls are crowned with adobe bricks that are slightly offset outwards, like cornices. Between these cornices are supported the trusses that structure the roof, and the cover that is conserved maintains a framework of double bamboo and different layers of wheat straw, tied to the trusses. In an interview with Mr. Pedro Castro Pacha (Fig. 8), who was born in the locality and is also a builder, he points out that the last houses built according to tradition in this community, were built until 1958.

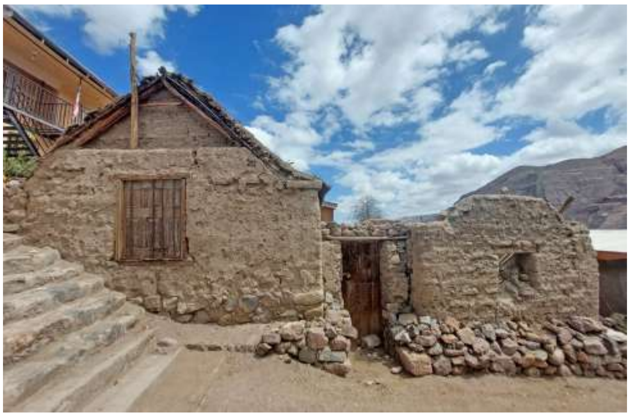

Figure 7: Housing Typology 1. Village of Huaviña.
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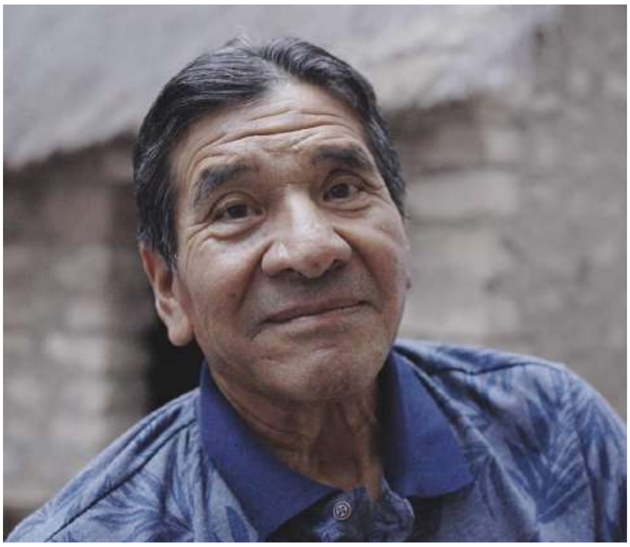

Figure 8: Mr. Pedro Castro Pacha.
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The following is part of his testimony:

"Once the adobe bricks and mortar clay were made –digging came first- a stone foundation was laid and then the walls were erected. Generally the foundation was one metre high: 50 centimetres of stone below and at least 50 centimetres above, all properly aligned. This gave the house firmness and also made it rainproof. The adobe was then laid on top of the stone foundation. The adobe was never laid lengthwise, as if to make more progress. What people cared about was that the adobe was laid transversally to give the house and the wall firmness. And the corners were lock, one adobe facing on one side and the other adobe facing the other side. Walls were built that way.

The houses' walls were 2.70 to 3 metres high. The truss, which was made of rustic wood from the village itself, rested at this height. The wood beams came from Willow (Salix babylonica), Molle (Schinus molle) and sometimes Apama (Myrica pavonis) or Pear Trees. So those trees, the straightest ones, were always cut in December. Because that's when the first rains start. And those trunks would be lashed by the riverside, waiting for the first downpour of water. When the water rose, the trunks were thrown into the river to be turned over, crushed and peeled by the stones. As the tree was fresh, the raw sap inside would contract and make it firmer. This process of the trunks being hit and carried away by the river is called 'aguachar'. In other words, when the trunk is 'aguachado', it is firm, it is hard. And then the trunks of trees were taken out of the river and laid to dry.

Red clay pigment mixed with natural red fruits and sometimes aniline were added to these beams, which have been laid in a long gutter. All this was used as mothproofing and truss colouring (Fig. 9). Then on the trusses, two cane units were placed together by two others in the opposite direction, making squares of 20 by 20 centimetres. The cane crossings were lashed together with 'huato'. This was the name given to the potato sack made of rubber or hemp, all naturally made. The trusses were separated every 80 centimetres or one metre. The cane mat was tied to the trusses with leather (usually llama leather) which is harder and was cut into one-centimetre strips and soaked to soften. This was then used to tie the canes to the trusses".

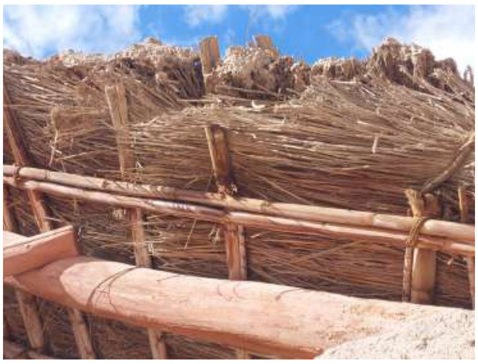

Figure 9: Traditional roof at village of Huaviña.
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3.2 THE CASABLANCA COMMUNITY CASE

In the case of the Casablanca Hospital site, 5 kilometres from the town of Tarapacá, dating back to colonial times and also used as a convent, the construction system consists of mixed masonry of adobe laid lengthwise and stone in the side row, which are laid in mud mortar (Fig. 10.a). Thanks to the alternation of the order of the materials laid between each row, good bonding, resistance and wall thickness have been obtained (Fig. 10.c). The corners are orthogonal and have been reinforced with adobe bricks in each row, alternating between the walls in a jagged pattern in shape of teeth (Fig. 10.b). Some mud plaster is also preserved as covering. The building has a surface area of approximately 1,800 square metres and despite its state of ruin, all the walls have been preserved in different states, with two distinct levels, a staircase and an interior courtyard surrounded by several rooms in the lower section, where the main entrance would have once stood.

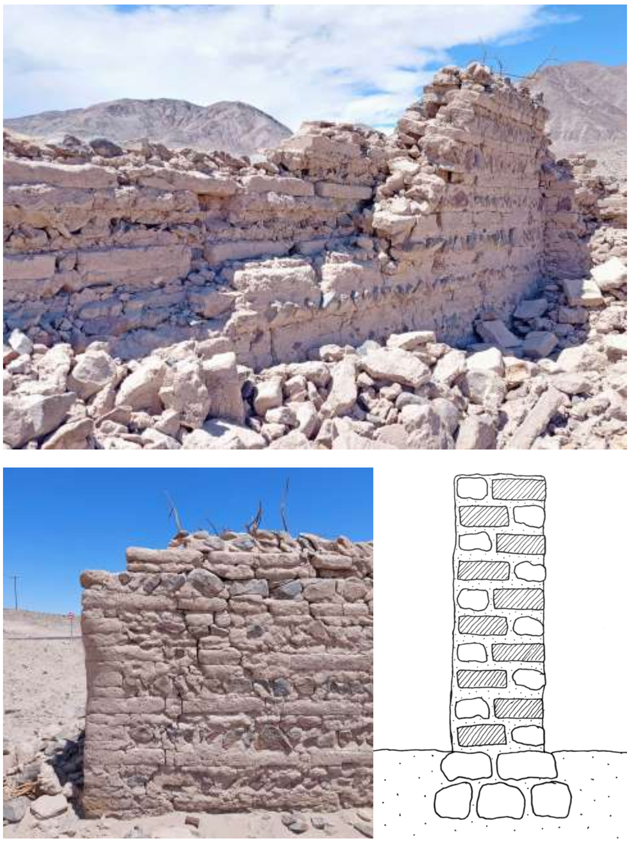

Figure 10: Construction system in the former Casablanca Hospital and Convent. a) and b) Views of walls c) Wall thickness diagram
© Photographs and diagram by J. Quiroz Bravo, 2023

3.3 THE HUASQUIÑA COMMUNITY CASE

This village is located in the Aroma Valley. The village plot features two well-defined public spaces that are still preserved. One is the square in front of the church and the other is the Altar of the May´s Cross. The altar, in addition to being a crossroad for the three levels of alleys in the village, has terraced floors, walls and seats made of earth, stone and wood, which allow people to meet and rest between the daily domestic and agricultural work.

In his testimony, Mr. Ricardo Perea Ríos talks about the traditional construction techniques in the village of Huasquiña, clarifying that he only participated in disassembling and repairing some houses:

“Mud and stone were used here for building. The ‘barreras’ (mud pits) were special places where there was a mud with bonding capacity; so it wasn’t just any earth that was used to make the mortar. In general, the mud was white or ash-coloured. And after carrying it to the place where the building was going to be erected, the mud was mixed with wheat straw, which was produced in the village itself. The stones and adobe bricks were then glued together with this mixture.

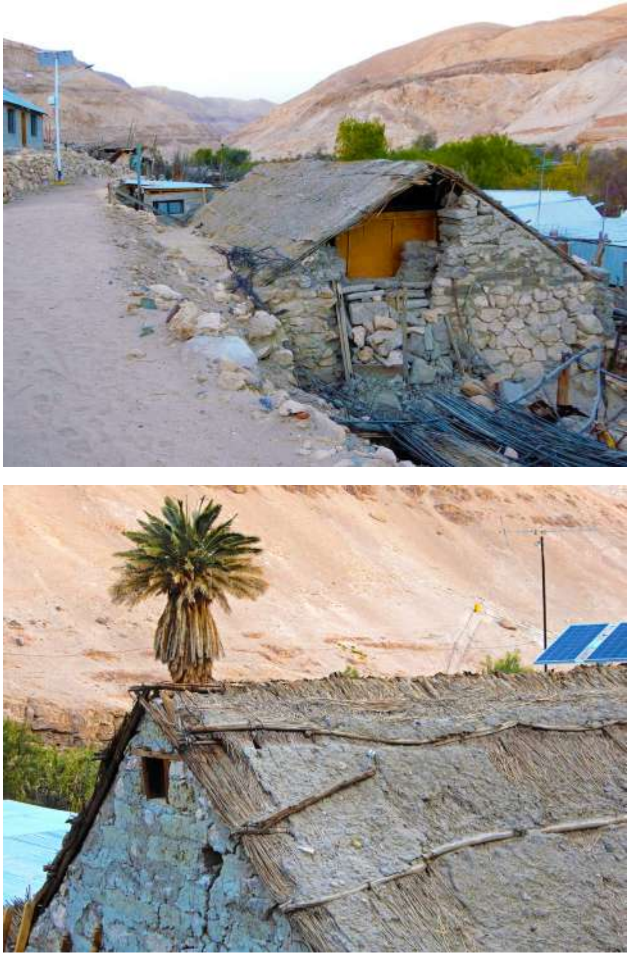

Figure 11: Housing Typology 2. Village of Huasquiña.
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After the mud was made and the adobe and stones were ready, a hole of up to one metre deep was dug and then the foundation was laid using mud and large stones. Here there is a stone that we call ‘white stone’, which was used for building. It is water resistant and to this day it lasts for a long time.

For roofing, local wood or beams from the village trees were used. They used the Molle trees and Willows. The straightest sticks were cut. Then, a procedure called 'beneficiar' was used to mothproof the wood and make it ready more quickly. This process consisted in burning the beams for several hours; then they were taken out and the bark was removed, leaving their white colour. Afterwards, when the beams had to be put in place, they were evened with an adze; then the beams were evened and trusses were made for roofing. Everything had to be made with local materials; there was no other material available (Fig. 11). The houses were built in this way until 1960 or so".

3.4 THE SIPIZA COMMUNITY CASE

The village of Sipiza is located in the Sotoca valley, in the upper part of the foothills. Here the proximity to the volcanic area is evident, due to the greater availability of rocks, mainly limestone and andesite. Therefore the walls are made of stones set in clay mortar, from the base to the crown. The buildings' floor plans are rectangular in shape and the roofs are gabled. Among the dwellings stand some buildings with highly decorative elements such as arches, imposts and mouldings carved on white limestone. The mortar on which the stones are laid is also white. This shows the high purity of the quarries (Fig. 12). There are also carvings on two white stones, the iconic scallop shell reminiscient of the road to Santiago de Compostela, and a preserved wooden door carved with phytomorphic figures, with clear baroque influences if compared to elements preserved in the churches. Although it is not possible to date the making of these elements, it suggests that these pieces are ancient. Similarly, the stones on the walls, with some areas of limestone and others of andesite, are highly expressive and could also be associated with a baroque aesthetic, lacking the neatness of the rows, which is the method of construction in the villages of the lower sectors of the valleys in the Tarapacá region.

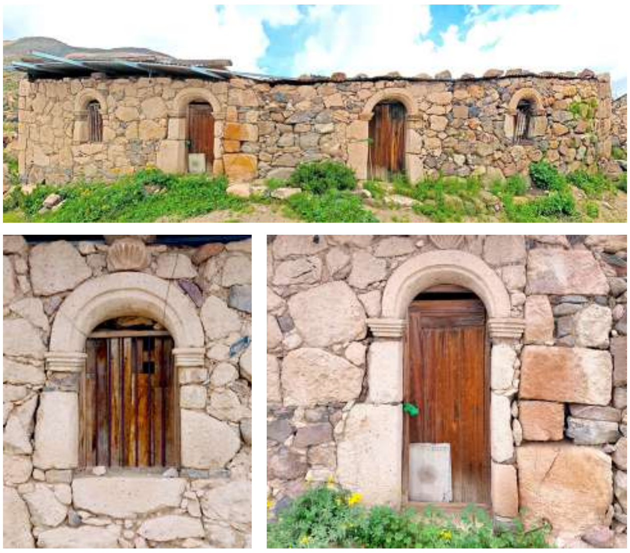

Figure 12: Housing Typology 3. Stones set in clay mortar and details of arches, imposts and ornaments carved in limestone.
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CONCLUSIONS

Although a time horizon and the causes that mark the end of vernacular earthen architecture's construction practices that have been sustained by the local indigenous communities for about 3 thousand years have been exposed here, this study focuses on the communities themselves, which have collaborated in the presentation of cases. This coincides with the urgency of conveying the knowledge inherited through their grandparents' memories, with the specific objective of recovering the earthen architecture heritage that they still preserve in their territories. In addition, bibliographic sources, mainly from archaeology, have made a significant contribution for the identification of some construction techniques. Consequently, field work has shown the continuity of the double-row system for enhancing wall thickness, as described for the site in the village of Caserones. This continuity has also been ascertained in this research, in the old colonial/republican site of Tarapacá Hospital, located in the community of Casablanca, which features the successful technique of mixing adobe blocks and stones laid offset between the rows. Although the building is in an overall run-down state, the preservation of all the walls demonstrates good resistance and bonding. This, in addition to the technology used, is due to the quality of the materials.
In turn the cases studies, focused on earthen architecture for domestic/housing use, show a diversity of spatial, technological and aesthetic typologies, including the circular pattern seen in a photograph of Sibaya in 1950 (Fig. 4). This reinforces the identity of the communities and promotes feasible adaptation projects subject to different requirements.

Finally, the remarkable testimonies of grandparents who maintain ancestral ritual and agricultural production practices, restate the importance of public spaces and the community character underlying the village social fabric. This could result in a unified proposal for the comprehensive restoration of earthen architecture and vernacular heritage that has been built in the villages based on environmental value and cultural landscape, beyond the reconstruction of housing units. In addition, these memories on constructive knowledge are evidence of an ecological system that is at risk, feasible to restore as long as some cultivated building materials regain their value and use.

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THE EARTHEN ARCHITECTURE OF HASSAN FATHY OR HOW ARCHITECTURE CAN CONTRIBUTE TO THE PRESERVATION OF THE NILE'S HERITAGE

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SUMMARY

Known for his projects in mud brick, the Egyptian architect Hassan Fathy has not always built this way. In fact, his first encounter with earthen architecture took place in 1941, while he was visiting archeological sites with his students. This 'Nubian miracle' as he liked to describe it created a major shift in his way of conceiving and thinking space as he immediately started to incorporate Nubian elements such as vaults or mud bricks, into his architectural language. This proposal aims to highlight the way Hassan Fathy re-interpretated the Nubian architectural language and managed to give it a new contemporaneity, a new life in the architectural landscape. For this purpose, it is the Hamed Said house that is highlighted since it is his first successful experimentation with earthen buildings. This essay also highlights the constant effort of the architect to promote and diffuse the ancient Nile Valley's heritage and his major role in the preservation of its vernacular architecture that was threatened to disappear.

INTRODUCTION

"Build architecture from what is beneath your feet" is without a doubt one of the most popular sayings of Hassan Fathy. Often considered as the "Architect of the poor", Hassan Fathy has dedicated his career to the preservation of the Egyptian heritage and has long worked to highlight its modernity. While the influence of the Islamic Architecture is clearly present in his work, one cannot deny that his way of conceiving also crystallizes the Nubian know-how. His first encounter with Nubian architecture, in 1941, created a major shift in in his way of conceiving and thinking space. Indeed, he immediately started to incorporate Nubian elements such as vaults or mud bricks into his architectural language. In this context, one can wonder why an architect with such a classical formation and background would suddenly become interested in more vernacular forms? But more importantly, how does he manage to revitalize these traditional constructions in order to preserve the knowledge they entailed? In order to answer these questions, this paper will first explore the conditions of the first encounter of Hassan Fathy with the Nubian architecture. Then, we will cover the specificities of these vernacular dwellings by going through their spatial features and constructive techniques. Finally, will analyze the Hamed Said house built in 1942 by Hassan Fathy, which incarnates his first application of mud brick construction after traveling to Nubia. According to Viola Bertini, this building "already contained most of the elements that would form Fathy's design concept – that is, his search for 'a felt space' capable to 'convey an Arab feeling', which can be found both in the New Gourna village and in most of his following projects" (Bertini 2022). This proposal will ultimately attempt to showcase how building while bearing in mind traditional construction processes of the Upper Egypt and reintroducing them to a contemporary architecture can prove to be effective in preserving the Nile's Heritage and passing on its lessons to future generations. Since, as Hassan Fathy mentioned; "the survival of traditional societies over hundreds and thousand years indicates that they surely possess knowledge that can still be of great value either in its original form or as the basis for new developments" (Fathy 1986, p. XVI).

1. HASSAN FATHY AND THE NUBIAN MIRACLE

"The Barefoot Architect", "the guru", "the Egyptian ambition" (Monnet 2013, p. 12; Santelli 2011) … and so many other adjectives were and are still used to describe Hassan Bey and to mirror the resounding impact he had on the Egyptian architectural panorama of the 20th century. A forerunner at heart, Fathy has long fascinated by his more than avant-garde attachment to an architecture that is particularly respectful of its environment and accessible to the poorest. Indeed, it was long before the so-called ecologists that he "drew the attention of urban planning 'decision-makers' to the need to build according to the environment, the materials available locally and the way of life of the inhabitants" (Rulleau 1981). Throughout his career, he endeavored to highlight Egypt's traditions through the architectural language he deployed in the hope of renewing the creed of the people "in their own culture" (Frigo 2018).

Born on 23 March 1900 in Alexandria (where he lived until he was six years old), Hassan Fathy grew up in a family from the Egyptian bourgeoisie and benefited from a "European" education which was to be at the origin of his complex personality, oscillating between East and West. Indeed, at a very young age, he entered the British School in Cairo, and he continued his studies in architecture at the Polytechnic School of Fouad I University from which he graduated in 1926. At that time, Egypt was booming and there were plenty of opportunities for architects. Thus, the young graduate joined the Cairo Municipal Affairs Department upon completion of his studies, where he stayed for four years during which he put into practice the neoclassical training he had received and his production was "marked by a form of international eclecticism which, essentially fluctuated between soft modernity and Art Deco" (El Wakil 2013, p. 48). His first project, the School of Talkha (1928), with its neo-Greek resonance, perfectly crystallizes the common style of the time. In 1930, when he left the administration to collaborate with his fellow Ahmad Husni 'Umar, his architectural expression did not change: "alone or with Husni, he carried out one modern project after another, with a 'Deco' modernism that qualified part of the Cairo architectural production of the interwar period (El Wakil 2013, p. 50). In fact, James Steele indicates that Hassan Fathy was unconsciously part of a form of Orientalism since he was himself influenced by the occidental education he received. Therefore, it seems natural that Hassan Fathy would be predisposed to adulate and replicate the style in vogue in the West: he initially wanted to imitate the culture which was presented to him as superior (Steele 1997, p. 6) (Fig. 1).

However, few records survive from this period. Hassan Fathy did not really refer to it, as if he was trying to erase any possible trace of admiration for the Western architectural model: "it is difficult to attempt to reconstruct the beginnings of Fathy's career, as the documents are fragmentary […] either these documents have naturally disappeared during successive moves, or they have been eliminated by the architect himself" (El Wakil 2013, p. 47). In an interview for the newspaper Le Monde, Hassan Fathy admitted that it took him ten years to forget what he had learned in school (Rulleau 1981). Two years later, he confides to Salma Samar Damluji about it and strongly denounces the teaching that, in a way, pushed him to self-colonize. He declared: "we studied architecture as if it were exotic, the architecture of remote countries. And we studied it in archeology, not architecture. In fact, it is classical architecture that is exotic. This is self-colonization" (Fathy 1983).

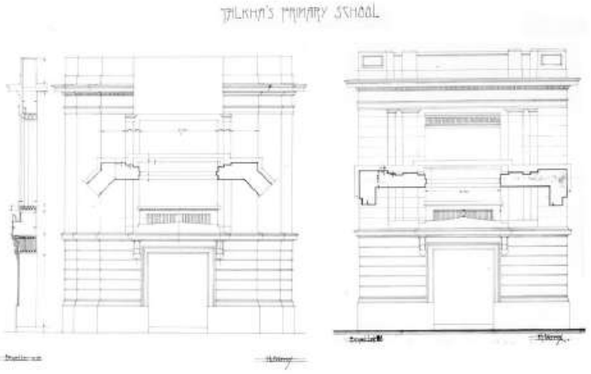

Figure 1: H. Fathy, Primary School, Talkha, 1928.
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From 1938 onwards, he ceased to be in the grip of the occident and surreptitiously introduced few components of the Cairene architecture: "the traditional vocabulary of arches and mashrabiyyas replaced the rectilinear lintels, rectangular perforations, and glass turrets referring to the staircase" (El Wakil 2013, p. 62). Besides, the young architect reasoning was precipitated by the political and social context of Egypt. Indeed, the Montreux agreements were immediately followed by the creation of an Egyptian associative movement and sketched the beginnings of a fertile and emancipating intellectual atmosphere. Several major figures were involved in this Egyptian intellectual renaissance and influenced (directly or not) Hassan Fathy's thinking. This collective emulation revolved around a single constatation: the decline of Egyptian civilization to the benefit of Western civilization and aimed for the reconstitution of a cultural identity. This led Hassan Fathy to drastically change his approach, to renounce to European archetypes and to base his representations on the everyday rural life instead. Moreover, Fathy abandoned the codes and systems of representation that he had been taught. He seized new tools such as paint and aquarelle and annotated his documents in Arabic instead of French or English; and used a bird or a tortoise to indicate the North (El Wakil 2013, p. 83). The projects he carried out during the 1940s reflect this paradigm shift, notably by the introversion of their plan and the introduction of the qa'a as a centrepiece.

Gradually, Hassan Fathy, embarked on a quest to discover the architectural traditions of his people and this search for his own origins took him to Nubia. Hassan Fathy had its first encounter with Nubian architecture in February 1941, while he was visiting archeological sites with his students. At that time, he was struggling with a project commissioned by the Royal Society of Agriculture for which his was supposed to build a farm in Bathim in order to improve farmers' conditions. Despite several attempts, he and his team could not find a roofing solution involving the mud as a material and a vault without any centering. Seeing him dejected, his brother who was working on the Aswan Dam advised him to study Nubian constructive methods since he noticed that their vaults did not require any centering (El-Shorbagy 2001, p. 32). In the hope of finding a solution, he formed a group of students and professors to examine the architecture of this region, which was then unknown to him. Fortunately, Nubia did not disappoint, he states (Fathy, 1969, pp. 6-7):

"On entering the first village, Gharb Aswan, I knew that I had found what I had come for. It was a new world for me, a whole village of spacious, lovely, clean and harmonious houses each one more beautiful than the next. There was nothing else like it in Egypt, perhaps from a Hoggar hidden in the heart of the Great Sahara - whose architecture had been preserved for centuries uncontaminated by foreign influences […] I realized that I was looking at the living survivor of traditional Egyptian architecture, at a way of building that was a natural growth in the landscape […]. It was like a vision of architecture before the Fall: before money, industry, greed and snobbery had severed architecture from its true roots in nature."

This unexpected discovery changed Fathy's perspective and moved him to the very core, hence this travel turned out to be a turning point in his architectural conception and spatial poetics. Therefore, he would later describe this journey as 'the Nubian miracle'.

2. NUBIA, EARTHERN POETICS AND ARCHITECTURAL LEGACY

For those not familiar with the term Nubia, it refers to the name of a region of the Nile River valley which nowadays, encompasses the south of Egypt and the north of Sudan, between the cities of Aswan and Khartoum. The region is characterized by a hot and arid climate, with temperatures often exceeding 40 degrees Celsius. The origin of the name "Nubia" is uncertain, but it is believed to have derived from the ancient Egyptian word "nub," which means "gold" (Elsebae 2015, p. 89). This is thought to refer to the region's abundant gold reserves, which were highly valued in ancient times. In its original form, the Nubia consisted of three main clans: the Kenuz (north), the Arabs who lived in the central settlements and the Kushaf or Vaduga who were living in the south (Serageldin 1982, p. 50). Nubia was a very isolated region, and the Nubians were considered as 'a definable group' (Kamel, Abdel-hadi 2012, p. 77) as they lived in autarchy and had not been influenced by the variable changes happened in Egypt throughout the years until the construction of the high dam in 1959 (Bayoumi 2016, p. 877).

It is axiomatic that the traditions preserved by the Nubians were not only social and political. They were also cultural and artistic. Hence, they have jealously preserved their architecture from any foreign influence. As Hassan Fathy points out, the construction methods still in use in Upper Egypt and Nubia have been passed down from generation to generation since the earliest times (Fathy 1951, p. 19). Shaped by the region's geography and climate, the Nubian architecture used mud bricks for their thermal properties, and forms that enhance the internal comfort such as domes, vaults and courtyards. Indeed, in Aswan, several examples such as the monastery of St Simeon, the granaries of the Ramasseum testify to the use of these techniques (the mud brick vaults) from the first Egyptian dynasties. In his essay Inspired by Nubia, Hassan Fathy conveys (Fathy 1962):

"Visiting these villages, one is struck by the artistic ability of the builders of Aswan, their creativity and the harmonious proportions of their buildings, and at the same time by their technical accomplishment particularly in building semicircular vaulted roofs of adobe or baked mud bricks, and domes constructed without wooden centering or supports using methods handed down from generation to generation since the days of Old Kingdom."

From antiquity to our time, these constructive methods were preserved and developed into a unique architectural language. The Nubian knew how to incorporate and diffuse the memory of the ancient world in their domestic architecture, creating a very singular spatial poetic. It is salient to note that their houses are specifically conceived to be both practical and aesthetically pleasing with a focus on creating a cool and comfortable living environment. In consequence, they were usually articulated around an open courtyard which engenders the very nucleus of the system (Bertini 2018, p. 66), and functions as an intimate and secluded space. In the majority of instances, the traditional Nubian house is very spacious, with several rooms dedicated to hosting guests such as the mandara, which has its very own entrance and windows that open directly to the outside. Conversely, the common living area dedicated to the household members provides direct access to the central courtyard, featuring a loggia covered by an overhead canopy of branches and palm fronds, more formally referred to as a khaymah (Bertini, 2018, p. 66). Technically speaking, the natural ventilation is on one hand guaranteed by the wooden or brick lattices placed over the small opening and windows. On the other hand, the vaulted structures insured the thermal comfort since their inertia resulting from the considerable thickness of the unfired clay walls, offers a notable reduction in temperature fluctuations within the edifice.

The Nubian vaults are constructed using an innovative technique that dispenses of the need for temporary support structures or centering. This is made possible thanks to a combination of factors, including the remarkable adhesive properties of the mud mortar, the unique form of the vault, and the gradual incline of the successive layers of mud bricks (Gargiulo, Bergamasco 2006, p. 1215). Each layer of bricks is precisely positioned in such a way as to create a self-supporting arch, which gradually gains strength and stability as additional layers are added.

The thickness of the supporting wall, which is greater than that of the lateral walls, further reinforces the structural integrity of the vault. Maria Rosaria Gargiulo and Immacolata Bergamasco provide a more comprehensive analysis of the construction methodology (2006, p. 1213):

> "When making domes, they used a string anchored to a rivet fixed into the ground in the centre of the circular space to be covered. They used to place at the free end of the string a wooden bar orthogonal to the string itself, that worked as a guide to the proper positioning of the bricks."

Yet, this ingenious construction process remains relatively simple and does not require any machinery nor sophisticated tools, which makes it accessible to a wide range of people, including those without formal construction training. Additionally, the use of locally sourced materials makes the Nubian Vault an affordable and sustainable building technique and reinforce its accessibility.

Collectively, these features produce a resilient and durable strict avoiding costly and time-consuming construction of temporary support structures. This is a testament to the ingenuity and resourcefulness of the Nubian people as Hassan Fathy states (Fathy 1962):

> "The villages that the Aswan builders erected in only a year were fully in keeping with both their environment and the character of the Nubian themselves, as if they had emerged organically over centuries from the land where they were constructed. The creation of these villages was a great architectural achievement, unparalleled in the oeuvre of the great international architects of today."

Furthermore, the Nubian Vault also has aesthetic benefits. Its unique arched shape and decorative elements such as the intricate patterns and designs carved or painted onto the harmonious proportions make it a distinctive and attractive architectural style. In Nubian architecture, the aesthetic of the dwellings held utmost significance in the design process since each house "was an expression of the identity of the home's owner" (Bertini 2018, p. 68). Indeed, the Nubian facades are renowned for their intricate and colorful paintings depicting scenes from daily life, religious ceremonies, or symbols to protect the house and its inhabitant. The use of vivid colors and bold patterns originated in ancient times as a means to margin off evil spirits. Viola Bertini observes that these paintings frequently incorporate pictograms of hieroglyphs which serve to solidify the persistence of ancient superstitions which are still, nowadays a crucial element of popular culture. In the eyes of Hassan Fathy, these paintings alone were a subject worthy of a paper; he also indicates that it is women who added these "enchanting decorative touches, giving the building a feeling of homeliness perfectly in keeping with the architecture" (Fathy 1962).

3. REVIVING THE NUBIAN ARCHITECTURE: THE WORK OF HASSAN FATHY

"Would we, as artists and architects, be able to save this vernacular legacy from the rising waters of Lake Nasser for future generations, just as the Ancient Egyptian temples of Nubia have been saved? Or should it vanish without trace, like a lovely dream?" (Fathy 1962).

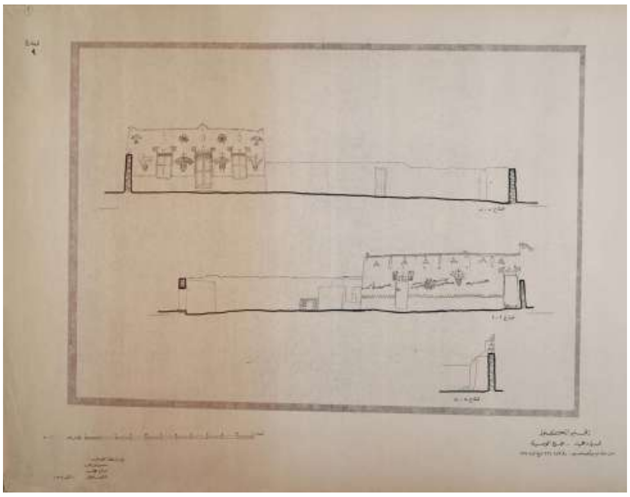

Figure 2: H. Fathy, Survey's of the Nubian area, Bayt Malik 'Abbas Aḥmad Ḥasbou, Kunuz Neighbourhood.

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Faced with the prospect of a threatened cultural heritage, Hassan Fathy penned these poignant words lamenting the gradual disappearance of the Nubian's vernacular architecture. Indeed, at that time, the Nubian territory had already encountered flooding on two occasions, each time causing significant harm to the local population and their heritage. It is noteworthy that during the prior dam constructions in 1902 and 1933, no sufficient investigations were conducted to ensure the adequate resettlement of the locals and the conservation of their unique culture and customs (Fathy 1962). To record the specificities of their architecture, he Hassan Fathy conducted a survey in the districts of Nubah, Kunuz and Al-Arab as part of the creation of the High Institute of Social Anthropology and Folk art (Fig. 2). While this project was left unfinished, the invaluable record of 29 architectural drawings of dwellings in the heart of Aswan shed light on the construction techniques and methods of the village rebuilt between 1934 and 1946. This documentation not only served as a tribute to the traditional Nubian architecture, but also highlighted the need to preserve and promote these techniques in the face of modernization and globalization. Hassan Fathy's commitment to preserving Nubian architecture went beyond documentation and research. He recognized the significance of using his architectural designs as a vehicle for promoting the Nubian tradition. As Viola Bertini highlights, "the story is told by the architecture projects that he developed after 1941" (Bertini 2018, 68) and the Hamed Said House cristallises the shifting point in his 'thesis of space' (Steele 1997, 54).

In fact, this project is considered as one of the most important of the Egyptian architect's career since "it was the first application of mud-brick construction and return to a traditional approach" (El-Shobargy 2001, p. 33). In 1942, a close friend to Hassan Fathy, Hamed Said asked for his expertise and services while he sought, with his wife, for a more permanent residence (Steele 1997, 54). In order to meet their desire to be connected to nature and their environment while having a quiet and peaceful place to work and live, Fathy incorporated the architectural elements he discovered in Nubia with the one from the Cairene medieval period. Consequently, the house was a simple domed studio space recalling the traditional qa'a with an adjoining swan dedicated for sleeping. Adjacent to the studio is a vaulted loggia which was completely opened on one side. Said describes:

"The first home of Art and Life was built in the early forties, a simple mud-brick construction on the edge of vegetation. The young palm trees, the fields around, the desert behind and the sky above welcomed it. It was not out of key. The trees grew, encircling it, and it nestled peacefully among them."

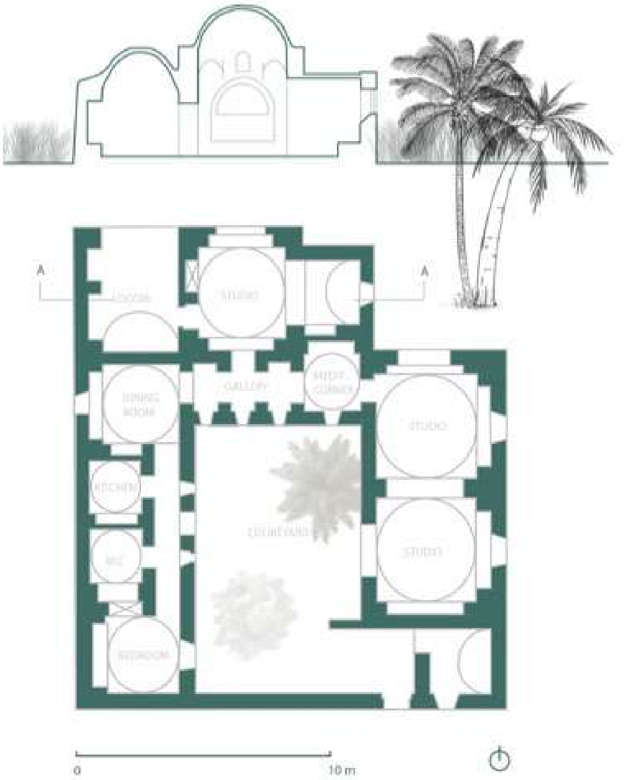


Figure 3: H. Fathy, Hamed Said House, 1945. Plan and section drawn from Fathy's archives in the RBSCL, The American University in Cairo. © Z. Bennouna

Amazed by the results of what he defined as 'a pottery and a building at the same time', Said asked for an extension which was built in 1945 (Steele 1997, p. 55). To reinforce the inter-relation between the building and nature, Fathy wrapped the next part around the existing trees. He was thereby able to create an inner courtyard to connect the two parts together. Furthermore, this link is emphasized by the creation of a gallery running throughout the original studio and connecting it to the newer and larger one. The gallery ends with a meditation room opening onto the best view of the inner courtyard (Fig. 3). According to James Steele this gallery was far more than a simple corridor, it "has an almost cloister-like feeling" (1997, p. 58). Even though the house was built in two different phases, the final result makes it difficult, if not impossible, to guess that this house was built in two different stages. The relationship between interior and exterior spaces smoothens the overall and anchors this project in a desire to build a space in harmony with its surroundings. In other terms, this perfectly corresponds to the initial request of the artist couple and Said states:

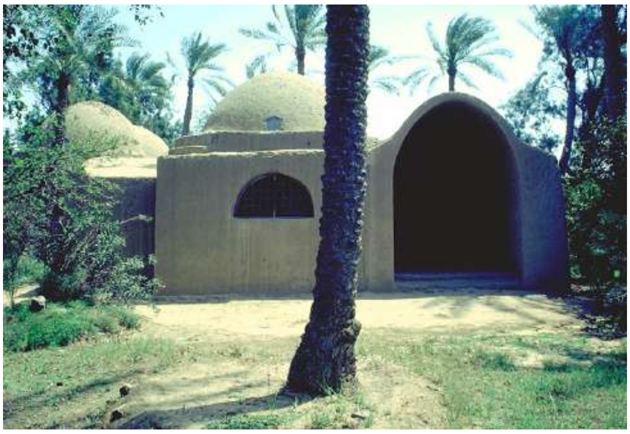
"The world became full of meaning and the Divine a verified presence. Work had become the redeemer. In this home, my wife and I thus lived and worked carrying on our search for art that would become a way of life and for a way of life that would become art."

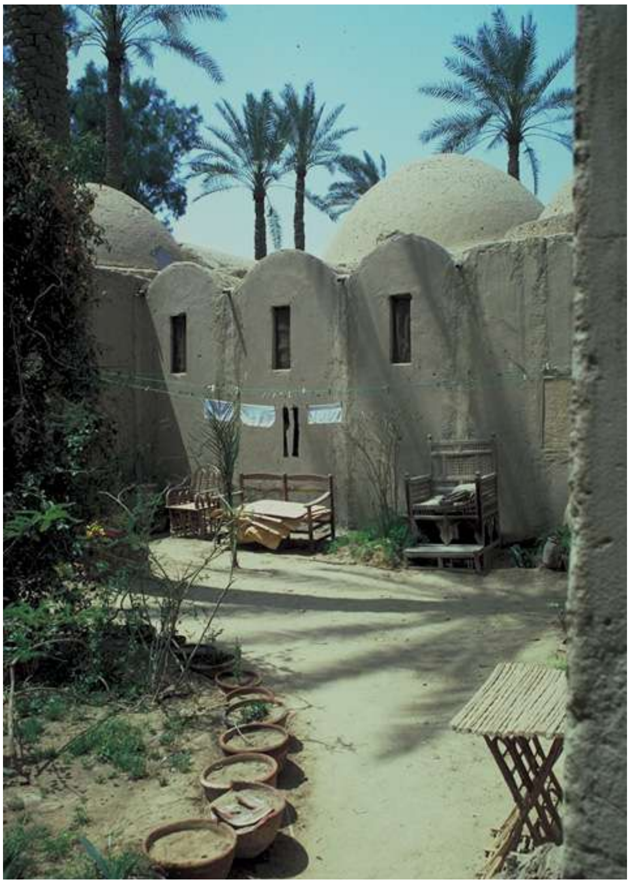
Once completed, the house hosted the meetings of the Friends of Art and Life since he considered his house as a "restatement of the original agrarian roots of Egyptian culture" (El-Shorbagy 2001, p. 36). For the group, Said's house symbolized a true expression of their principles which revolved around the harmony between people and their environment. By using this project as a platform for dissemination of the Nubian construction techniques, Hassan Fathy managed to promote and share them within the group and to put the vernacular architecture of this region under the spotlight. Moreover, this first house, built in mudbrick and following the Nubian tradition showed that these methods still find their application in modern architecture and that they are transposable to other regions of Egypt. This project marks the beginning of a series dedicated to earthen construction ranging from individual houses to entire villages. In 1963, after the Nubian's displacement, he addressed a letter to President Gamal Abdel Nasser to stress out the benefits of the vernacular building methods in the rural environment and to reiterate the importance of using mud as a material since it is the very material of the Nile. In this letter, he tries to deconstruct preconceived ideas about mud brick and warns that some people try to demonize it in favor of concrete which is far from being suitable to the Egyptian landscape and climate (Fathy 1963):

"Some people have unfortunately interpreted your statement regarding the need to raise the standard of rural housing […] as a call to eliminate the mud brick from our architectural vocabulary. […] Mud brick are far from lowly material: palaces may be built from them, just as shanty towns may be built from concrete. The villages of Nubia are testament to this fact."

Through his writing and buildings, Hassan Fathy portrayed a technique that has never been equaled and ensures that the Nubian architecture is more "beautiful and architecturally far more harmonious than any housing scheme built by any government or international organization around the world" (Fathy 1963). He believed that traditional Nubian building techniques offered a wealth of knowledge that could be harnessed to create low-cost, environmentally friendly homes for people in need. In addition, Fathy saw the preservation of Nubian architecture as a way to combat the destructive impact of modern industrialization on the built environment. According to him, the architect has a "moral obligation to consider whatever may affect the efficiency of the building and the people whom he is housing" (Fathy 1986, p. 6). He strongly supports the necessity of grasping their functional modalities before focusing on making them evolve and modernized (Fathy 1986, p. XXIII) :

"He (the architect) must renew from the moment it was abandoned and he must try to bridge the existing gap in its development by analyzing the elements of change, applying modern techniques to modify the valid methods established by our ancestors, and then developing new solutions that satisfy modern needs." (Figs. 4 and 5)





Figures 4 and 5: H. Fathy, Hamed Said House, 1945. Cairo, Egypt, A Catalogue of Visual Documents.
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Little by little, he set up an architectural language of his own by mixing the concept of the traditional Arab house with Nubian construction techniques. For Hassan Bey, the essential "is to learn […] that culture is the interaction between the intelligence of man and his environment to satisfy his physical, intellectual and spiritual needs" (Rulleau, 1981). His projects in mud were noteworthy and seduced the Egyptian Department of Antiquities which entrusted him, in 1945, with the project of relocating the old Gourna near the Valley of the Kings in Luxor (this project is more commonly known as the New Gourna or Gourna al-Gadida). More than just a boon for Hassan Fathy, the New Gourna embodied the opportunity to experiment with his architectural ideals on a grand scale. At the opposite of what is often portrayed, the New Gourna is far from being a new and instinctive architectural conception but rather the result of several technological, typological, and formal experiments renewed during the previous decade. This action of relocation was intended to be economical while resonating with the needs of the villagers. He imagined a model village, self-built by the peasants and made of raw earth, thus giving honor to local materials and traditional techniques. He aspires, through this prototype, to provide dignified housing for the peasants, the "Gournis". In doing so, Fathy adopts a very happy formula to describe his ambition: "It was (my goal) to build a village where the fellahs would lead the kind of life

I wish for them" (Fathy 1996, p. 23). But the life he imagined for them was not the one they wanted, which made it difficult for them to accept this new village. Indeed, the latter dreaming of "modern" housing, look with disdain at the vaults and earthen domes that are presented to them and many refuse to move into the New Gourna.

The reluctance of the inhabitants, the lack of craftsmen, the boycott of the lobbies and the disengagement of the state led, three years later in 1948, to the stop of the building site.

If the end of the construction site closes the unfortunate experience of this village, the publication of his book Gourna; a *Tale of Two Villages* (1969), ensures its continuity. To process this failure, Hassan Fathy prefers to exchange raw earth for ink to tell how the New Gourna, through its incompleteness, carries the dream of another way of building: the Nubian one. While Western public opinion sees Hassan Fathy as a "prophet" outlining the contours of what is nowadays called sustainable development, the reception of this project and those that will follow remains much more controversial in Egypt. Between those who accused the architect of wanting to lock the peasants in their poverty, those who tax him as an orientalist and others for whom the domes are only synonymous with funerary architecture, few will finally recognize that Fathy was acting for the happiness of the peasants. Against all odds, Hassan Fathy pursued his advocacy for the revival of Nubian and Egyptian architecture by theorizing it to facilitate it diffusion. In 1984, with the help of Salma Samar Damluji, he wrote *The Mud Brick Manual: Vault and Dome Construction* in order to help to overcome some of the problems that might be encountered when using this method to build dwellings for a large numbers in rural areas.

In a nutshell, Hassan Fathy never ceased to raise awareness about the importance of preserving and promoting the ancient Nile Valley's heritage. His commitment to the preservation of Nubian architecture extended beyond documentation and research. Through his writings, built projects, and advocacy, Fathy was able to play a key role in ensuring that this tradition was preserved and passed down to future generations, making sure that the cultural heritage of Egypt remained vibrant and alive. On top of that, not only did he participate in saving the Nubian vernacular architecture, but he also contributed to its revival in the modern buildings. In fact, he knew how to translate the various lessons learned from past experiences into a contemporary Arab architecture and this, without ever neglecting the human dimension. Nowadays, Hassan Fathy's legacy continues to inspire architects and designer to create environmentally and humanly sensitive architecture that mirrors the local context and promotes a sustainable development. Nevertheless, it is up to us to continue to raise awareness and educate rural populations on these ancestral techniques. Above all, it is our turn to protect Hassan Fathy's heritage which is nowadays in danger: most of his works are "neglected and allowed to decay and crumble" (El Wakil 2008).

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Brick making, Saqqara, Egypt © T. Joffroy

THEME 2

RAW AND
BUILDING MATERIALS

FIRST INSIGHTS INTO THE EARTHEN ARCHITECTURE OF THE SITE OF PLINTHINE

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SUMMARY

Kom el-Nogous, located to the west of Alexandria on the shores of Lake Mariut and the Mediterranean Sea, has been explored by the French mission of Taposiris Magna and Plinthine since 2012. It contains the remains of an Egyptian village that was occupied from the New Kingdom to the end of the Hellenistic period (mid-2nd mil. BCE-end of the 1st c. BCE) which shows a very dynamic phase of occupation during the 7th and 6th BCE. In all periods, the activity of its inhabitants was focused on wine production.

The ancient Greek name of the site is thought to be Plinthinè, mentioned by Herodotus and Strabo, which means “the city or construction in mud”. Indeed, almost all of the architecture on the site is made of this material, in particular mudbrick, although stone is also widely used.

Thanks to the support of the ANR’s Nile’s Earth project, a research programme concerning mudbrick constructions, their implementation and the materials used in them was launched on the site in 2022. It combines archaeological excavations, architectural surveys, sedimentological coring, field tests and physico-chemical analyses of materials.

The aim of this project is to gain a better understanding of the characteristics of the earth used in construction, to be able to compare the architectural implementations according to different periods and to identify the potential changes of places where raw material was extracted during these different periods.

INTRODUCTION

The site of Kom el-Nogous (ancient Plinthine), located to the west of Alexandria on the shores of Lake Mariut and the Mediterranean Sea, has been explored by the French mission of Taposiris Magna and Plinthine since 2012[1]. It contains the remains of an Egyptian settlement that was occupied from the New Kingdom (Boussac *et al.* 2015) until the end of the Ptolemaic period (Boussac, Redon 2022), i.e., from the mid-2nd mil. to the end of the 1st c. BCE (Fig. 1).

The nature of the settlement is probably linked to its location on the fringes of Egypt during the New Kingdom (Dhennin, Somaglino 2022). During the Saite period (7th-6th c. BCE), the activities of the inhabitants were focused on a traditional domestic economy, coupled with very intense viticulture (Boussac, Redon 2022; Redon 2019; Redon 2021; Redon, Vanpeene, Pesenti 2016). Wine production continued during the Ptolemaic period, after the arrival of Greek settlers (Redon *et al.* 2023).

The land around the village is ideal for growing vines. It extends over a rocky ridge of calcarenite which, on its northern and southern slopes, is covered by sediments that are perfectly compatible with the production of quality vines (unpublished analysis by M. Crépy). The region’s climate is

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[1] The mission is funded by the IFAO, French Ministry of Foreign Affairs and the HiSoMA research center with the kind support of the Egyptian Ministry of Antiquities. For more information, see www.taposiris.hypotheses.org which contains the complete bibliography of the mission.

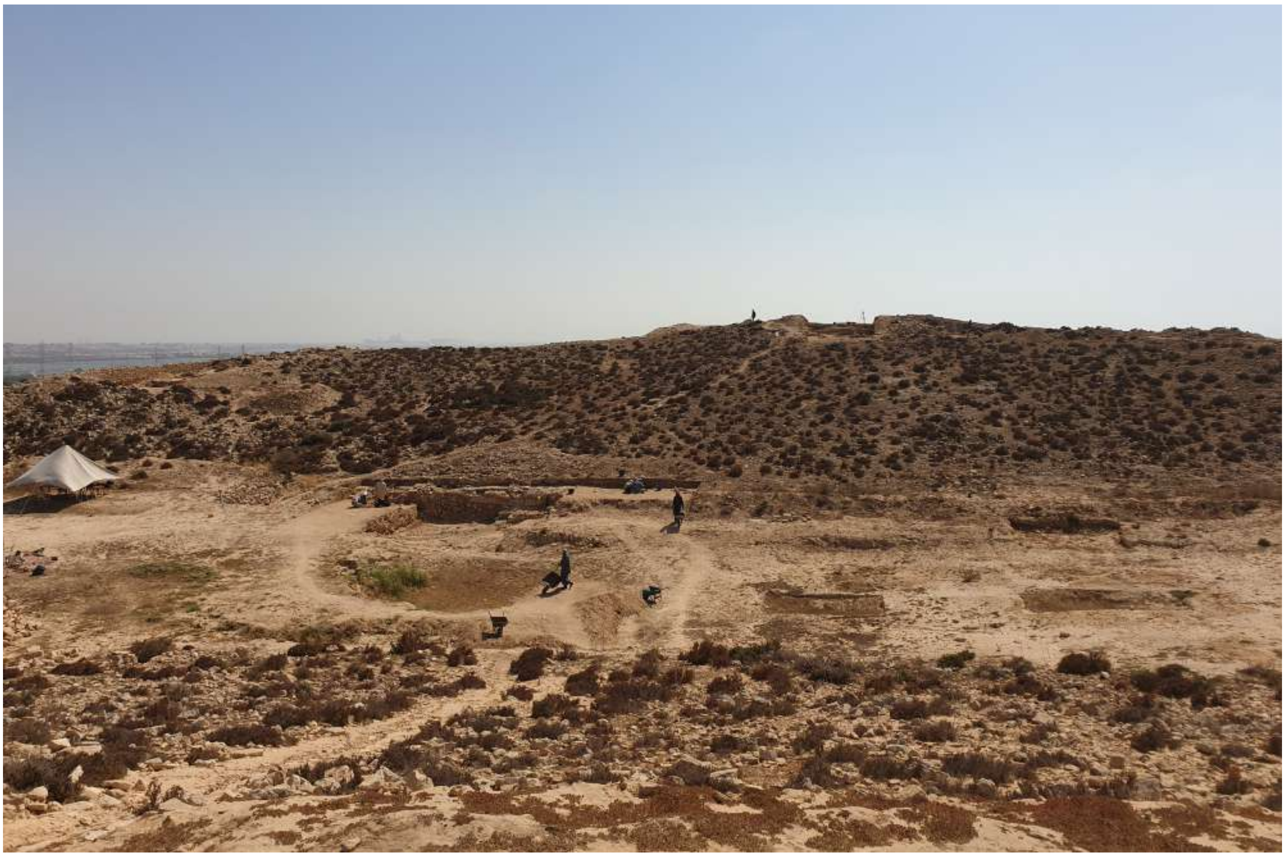

Figure 1: View of the site.
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also conducive to vine-growing. However, the region's proximity to the sea means that it is exposed to humid sea air and relatively strong winds. As a result, the buildings in the village were subject to wind erosion, water dissolution and high levels of salinity. This led the inhabitants of the village to adapt the construction methods and materials that were usually used in Egyptian architecture to the local environmental conditions. This involved the almost systematic construction of local stone flashings for the foundations and lower parts of the elevations. However, the upper parts of the walls, as well as the vaults and certain floors, were all made of mudbricks, the most widely used material in Egyptian construction.

In order to understand the choices that were made in this differentiated use, which evolved over time, a research programme concerning mudbrick constructions, their implementation and the materials used at Plinthine was launched on the site in 2022[2]. It combines archaeological excavations, architectural surveys, sedimentological coring, field tests and physico-chemical analyses of materials.

1. EARTHEN MATERIAL STUDY ON THE SITE OF PLINTHINE

The study of the earthen material used in the construction of Plinthine during Antiquity began in June 2022. The first campaign focused on the study of the archaeological earthen remains and the collection of 13 samples (bricks and plaster) (Fig. 2). These samples were analysed both in the field and the IFAO archaeometry laboratory in May 2023. Field observations and tests (7 normalised tests as part of the ANR's Nile's Earth project and based on Houben and Guillaud 2006) were used to define the characteristics of the raw materials that were used to build Plinthine and to identify their variations over time. The laboratory tests provided quantifiable data which enable comparisons to be made between the different samples. A second field mission was completed in May 2023 in order to continue the study of the architectural remains and this allowed the collection of 15 new samples (bricks, mortar and plaster) which will be analysed in the laboratory in 2024. In addition, sediments taken from around the excavation areas during hand-auger coring in 2020 and 2021 were included in this study. These sediments were analysed in the same way in the laboratory, enabling comparisons to be made between the "natural" soil and the soil used to build the site.

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[2] This work was supported by the French National Research Agency within the framework of the Nile's Earth project (ANR-21-CE27-0019-01).

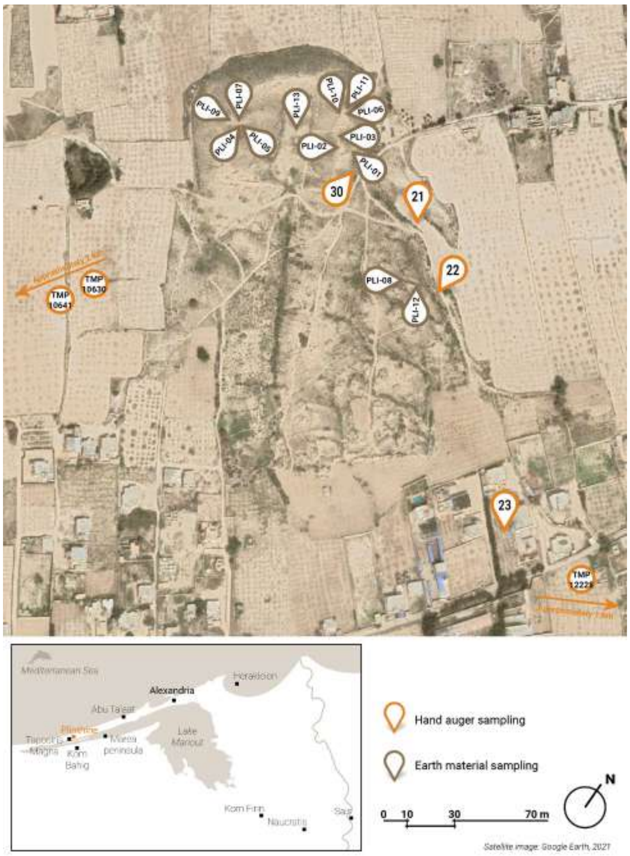

Figure 2: Site location and location of brick and core sampling.
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The laboratory work consisted of two tests: loss on ignition measurement (Heiri *et al.* 2001; Santisteban *et al.* 2004) and wet sieve granulometry (Miskovsky 2002).

Loss on ignition measurement is used to measure the gypsum, organic matter and carbonate content of a sample. Samples are dried and weighed before being heated for a set period of time. Their weight after the experiment is then used to define the percentage loss. Heating for 12 hours at 105°C eliminates gypsum, 4 hours at 550°C eliminates organic matter and 2 hours at 950°C eliminates carbonates.

Wet sieving was used to obtain granulometric curves for each sample. To do this, 11 sieves were used: a 2 mm, 1.6 mm, 1 mm, 0.63 mm, 0.5 mm, 0.4 mm, 0.315 mm, 0.2 mm, 0.1 mm, 0.063 mm and a 0.05 mm sieve.

We decided not to carry out sedimentometry on the sediments that were analysed to complete the granulometric curves below the 0.05 mm sieve. This choice was based on two factors. The first was that the samples which we analysed were already known to be construction materials, so we were not looking to define their qualities or their suitability for construction. The second was that the analyses carried out previously on natural soil sediments did not include this aspect. Therefore, in order to be able to compare the data obtained for both materials and natural soils, we decided to follow the same methodology as that applied previously. However, this decision does not rule out the possibility to carry out sedimentometry analysis at a later date in order to answer some specific scientific questions.

In general terms, the bricks used to build Plinthine, in all of the periods studied, are characterised by their very fine composition, the largest elements of which are crushed shell fragments of various sizes.

Sample	Sector	Type	Median (mm) *(P50)*	3rd Quartile (mm) *(P75)*	Percentile 99 (mm) *(P99)*
PLI-01	6	Brick	0.02 *	0.063	2
PLI-02	6	Brick	0.063	0.315	2
PLI-03	6	Brick	0.05	0.2	2
PLI-04	11	Plaster	0.05	0.2	2
PLI-05	11	Plaster	0.02 *	0.1	1
PLI-06	6	Brick	0.02 *	0.1	2
PLI-07	11	Brick	0.04	0.2	2
PLI-08	12	Brick	0.1	0.315	1.6
PLI-09	11	Brick	0.063	0.2	2
PLI-10	6	Brick	0.01 *	0.063	2
PLI-11	6	Brick	0.02 *	0.1	2
PLI-12	12	Brick	0.01 *	0.075	2
PLI-13	7	Brick	0.1	0.315	1

* supposed measurement (no information below 0.05 mm)

Table 1: Main grain size results used in this study.
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Visual observation of the composition also revealed, in the majority of the samples which were collected, the presence of white, round and smooth carbonated oolitic sand from the sea.

Finally, white and grey clay masses that measure a few centimetres in diameter were found in some bricks from the Saite and Ptolemaic periods. They appear to be the result of the addition of some very clayey material to the earth and may be the result of incomplete mixing during brick preparation.

The laboratory tests principally highlighted two interesting aspects of the composition of the earth used at Plinthine.
The particle size curves show a flat area between the 2 mm and 1 mm sieves (Fig. 3). This flatness is absent from the curves obtained for the natural soils and confirms the significant - and most likely deliberate - addition of shell fragments to the earthen material.

The results of the loss on ignition measurement show that most of the soils used for construction have a higher percentage of gypsum than the natural soils in the area and a lower percentage of carbonate. This would seem to indicate that the soil used is more clayey than the surrounding soils, or that clayey matter has been added, after being taken from a lower area in the Mariut basin and/or close to the sea.
In the same way, the percentage of organic matter in these materials shows that parts of it were added to the material used for construction.

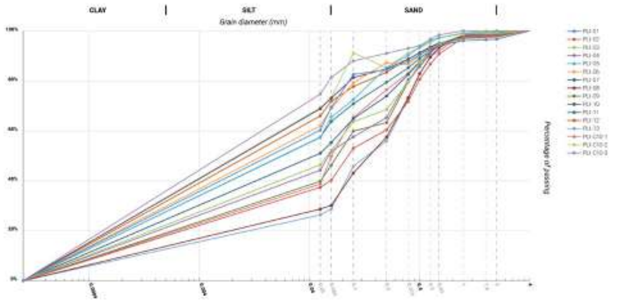

Figure 3: Granulometric curves for all the samples taken.
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2. EARTHEN MATERIAL DURING THE NEW KINGDOM

Only one sample (PLI-13) was taken from a New Kingdom brick in 2022 *(1550-1077 BCE)*, which limits the analyses that are possible. However, it is already possible to put forward some hypotheses.

The curve linked to this sample has one of the largest grain sizes and the lowest percentage of matter passing the last sieve (0.05 mm) out of all of the samples studied (Fig. 4). In addition to this specificity, the field analyses showed the low concentration or low activity of clay in this brick. These factors initially led us to suggest that the brick had remained on the surface for a long time and that its condition was the result of degradation caused by the action of water (eluviation) and/or wind.

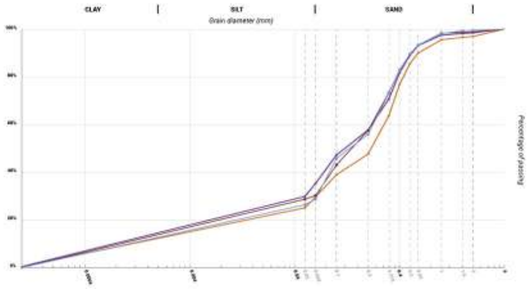

Figure 4: Superposition of the granulometric curves of PLI-13 (New Kingdom) and the core samples 23-45 and 30-45.
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However, with the data from the site coring, it is possible to establish similarities between this sample's curve and the shape of two soil samples taken from cores 23 and 30. This proves that a similar mixture exists elsewhere in the immediate vicinity, but as borehole 30 crossed some archaeological soils, it is likely that the sample from this place included at least parts of some mudbricks.

The sediments in the core 23 analysis come from a layer 45 cm below the current ground surface, around 20 cm above the last archaeological layers, which has been recognised as a natural deposit. In the light of this information, it seems possible to put forward the hypothesis that the construction material used by the builders was taken from directly beneath their feet. This surface soil, or at any rate subsurface soil, is available in low quantities because these deposits are generally thin but they would have been renewed over time from a mix of aeolian deposits from the sea (white sands) and the desert silts (Crépy 2023).

Excavations during the 2023 campaign in this sector revealed a superposition of phases of occupation during the New Kingdom, with successive consolidations and rebuilding of earlier walls. The bricks sampled this year were carefully studied in the field, revealing the use of a raw material that was poorly prepared, with potsherds (4 to 5 cm long), fragments of burnt calcarenite, unpounded shells, bones and sandy areas that were poorly mixed with the rest of the material.

This finding is compatible with the idea of successive phases of occupation and abandonment, with a probable re-use of previous building materials and everything that was mixed with them, as well as nearby raw materials (that might also have had time to regenerate) during each stage.

During the excavation season that has just ended, six new brick samples were taken in this sector. The new data obtained both in the field and through laboratory tests should provide a better understanding of the raw materials used during this period, and confirm or refute these initial hypotheses.

3. EARTHEN MATERIAL DURING THE SAITE PERIOD

The soil used for building in the Saite period (*664-525 BCE)* differs from that used previously due to its slightly yellower and lighter colour (*10YR 7/6 Yellow* according to the Munsell code reference) and, above all, the high cohesion of material in it.

The soil samples from the Saite period can be divided into two groups which have similar granulometric curves but a variation in the percentage of fine matter that they contain (from around 0.4 mm) (Fig. 5).

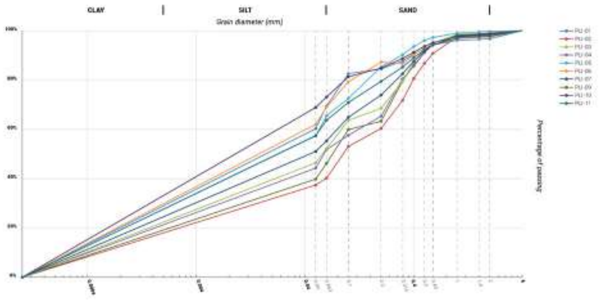

Figure 5: Granulometric cruve of earth used in the Saite period.
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The first group (*Saite 1*) includes samples PLI-01, PLI-05, PLI-06, PLI-10 and PLI-11. Above all, it is characterised by the fact that 55 to 65% of the material within these samples is smaller than 0.05 mm. The second group (*Saite 2*) includes samples PLI-02, PLI-03, PLI-04, PLI-07 and PLI-09. It is characterised by levels of material smaller than 0.05 mm that range from 35 to 50%. The first group (*Saite 1*) is thus distinct from the second due to its higher silt and clay composition. In addition, it was in some of the bricks from this group (PLI-06, PLI-10 and PLI-11) that clayey masses with a diameter of up to 2 cm were found. Some of these clayed masses, from PLI-10, were collected from this brick and analysed separately along with the rest of the samples under the names PLI-C10-1, PLI-C10-2 and PLI-C10-3.

The granulometric curves of two of these clayey samples seem to correspond to the curves of the group studied, albeit with a slightly higher percentage of material below 0.05 mm. The curve for the third sample (PLI-C10-1) seems to be similar to the Saite 2 group (Fig. 6).

The measurement of the gypsum content obtained by loss on ignition (between 1.5% and 2.5% gypsum) can be interpreted as a result of the highly clayey composition of these samples, which is much higher than the values obtained for the samples taken on site: clayey material is mainly found in the depression, presently occupied by Lake Mariut, located to the south, where evaporation rates and evaporite (including gypsum) formation have been a major process during the late Holocene (Warne and Stanley 1993; Crépy and Boussac 2021).

In addition, their granulometric curves are similar to samples taken on the edge of the present lake in areas that would have been swampy or partially watered during most of the Late Holocene (Crépy and Boussac 2021): TMP10630 and TMP10641 (Fig. 6).

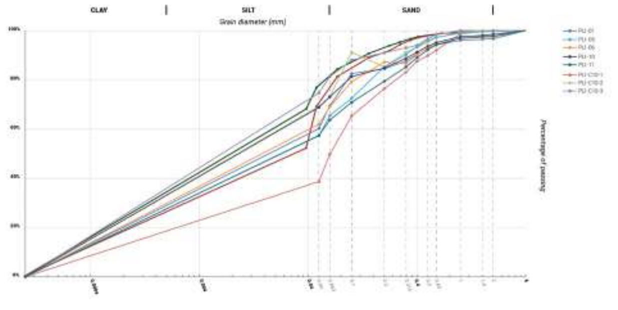

Figure 6: Superposition of the granulometric curves of Saite 1 group, clayed masses and sediments taken from swampy areas.
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The loss on ignition measurements of these clayed masses also resulted in the firing of the clays inside of them, which took on different colours (Fig. 7). This can be explained by the migrations of oxides in the clayey deposits during variations in underground water level in the context of hydromorphic soils. In both cases, these situations are compatible with the variations in colour that were observed in samples from the nearby site of Taposiris Magna, especially in the vicinity of the harbour (Boussac et al. forthcoming). The presence of different stages of clay oxidation also provides interesting information about the method used to extract the clay. For different layers of clay to be mixed in the same mudbrick, the raw material would have had to be removed from a working/quarry face and not just taken from the surface.

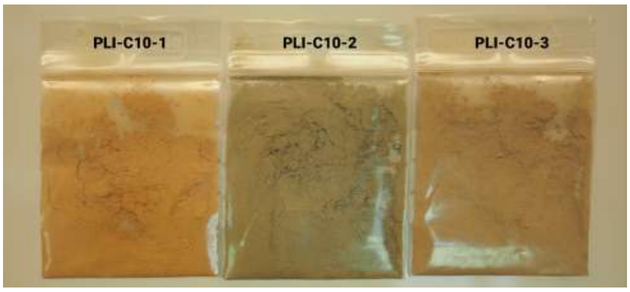

Figure 7: Colour variations between PLI-C10-1, PLI-C10-2 and PLI-C10-3 after baking at 950°C.
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The presence in these bricks of clayed masses, only partly mixed with the rest of the material, as well as the absence of similar granulometric curves in the natural sediments around the site, indicates that builders used a blend of raw materials. These could have been a mix of earth (probably close to the curves of the Saïte 2 group) and clay sources taken from nearby swampy areas. Representing the granulometric curve of these samples as a simple frequency instead of a cumulative frequency also provides some information (Fig. 8).

With the exception of two samples (PLI-05 and PLI-11), the breaks in the different granulometric curves are similar and occur on the same sieves. Therefore, it appears that, for these materials, no single raw material was used, but rather a blend of different materials. For the two samples PLI-05 and PLI-11, the breaks on the first sieves are similar, but the difference is in the break at 0.063 mm, which occurs at 0.1 mm. This is due to the natural grain size of the deposits extracted, which vary in coarseness from one area to another. On the contrary, the almost systematic mode observed for bricks in the coarse sand particle size class, absent from natural deposits, proves that mixing operations were carried out to obtain a good composition.

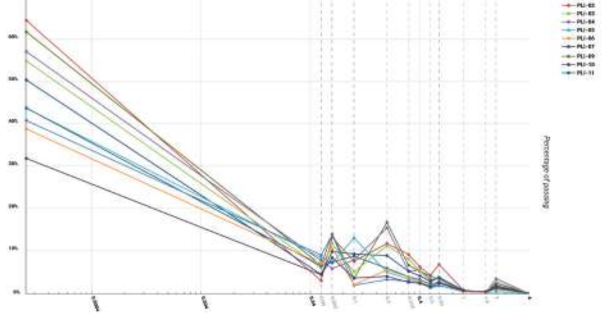

Figure 8: Simple frequency granulometric curve from the Saite groups.
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The use of this blend and the addition of clay to the unbaked earth is interesting because it was used in one of the earliest areas of Saite settlement on the site, one which is marked by a series of important features: a retaining wall or rampart, a tower house or tower and a wine press. The bricks that were sampled were taken both from the tower (BAT 606) and from a wall not far from it (MR 661). So, we have to consider some further questions about this blend. Is it present throughout the neighbourhood? Is it related to a single phase of construction? Similarly, it seems possible to ask questions about why this blend was produced. Was it linked to a new settlement and a lack of knowledge about the local soil? Was it created out of a desire to reinforce these major constructions and infrastructure by using a more clayey blend?

The results from the second group (*Saite 2*) seem to be similar to several other granulometric curves obtained during the coring campaign (Fig. 9), in particular the samples taken from cores 21 (21-77) and 22 (22-200), as well as one of those taken in the vicinity of the nearby archaeological site of Rahim (core 12, sample TMP 12228).

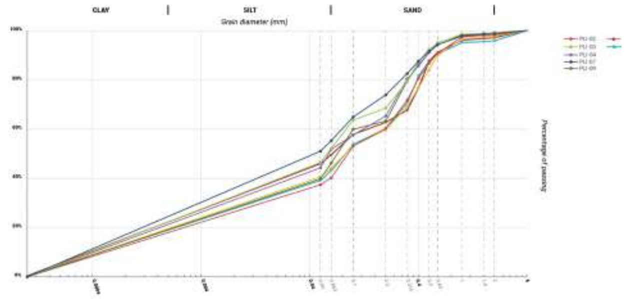

Figure 9: Superposition of the granulometric curves of the Saites 2 group and sediments from core sampling.
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However, considering the depth and location of two of these samples (200 cm and 50 cm respectively, in cores from which we also identified archaeological soils), it is possible that the samples were not taken from natural soil but from archaeological remains that have not yet been excavated. Regarding 21-77, on the contrary, the whole sedimentary column from the core is clearly the result of natural processes. But the similarity of the granulometric curves obtained does not allow us to conclude that local soil was used without being blended with any additional material.

In fact, it is possible that the soil used in this *Saite 2* group is also the result of a blend between local soil and clay sources from the lake. Although no poorly blended clay masses have been found yet in the bricks from this group, it is difficult to say with any certainty whether or not clay was added. It is in fact possible that the blend was more homogeneous and that the quantities of clay added were smaller.

One element seems to point in this direction: the simple frequency granulometric curves of the soils from the *Saite 1* and *Saite 2* groups show similar breaks and patterns (Fig. 8).

4. EARTHEN MATERIAL DURING THE PTOLEMAIC PERIOD

Two bricks from the Ptolemaic period *(331-30 BCE)* were sampled during the first field mission and were taken from the same building.

The first (PLI-08) is a brick that was collected almost on the surface and which was used in the masonry of a wall. It has low cohesion and mechanical strength. Its granulometric curve is similar to that of the brick sampled in the New Kingdom area and is characterised by its low percentage of the smallest components (less than 30% of its material is smaller than 0.05 mm) (Fig. 4).

The second brick (PLI-12) was taken from a structure inside a room, which would have been used for storage. It is characterised by its yellow colour, high cohesion and a granulometric curve that is very similar to the Saite 1 group (Fig. 10). In addition, a few small white clay masses were found inside of it.

The small number of samples taken from the Ptolemaic period and the large differences between these two samples make it impossible to study the bricks from this period in more detail. Nevertheless, the fact that there are similarities with the mudbricks used during the New Kingdom and the Saite period does not seem to be insignificant. Indeed, ancient levels of the kom are regularly pierced by Ptolemaic pits, so reuse of material could explain both the disparities between the different Ptolemaic bricks and the similarities of some of them with older building materials. This intense recycling activity could also be explained by the fact that the need for building materials was greater than the rate at which surface soil could be renewed by aeolian deposition in the area, or that the soils were preserved for agriculture on wider areas than before. Although the intensity of occupation of the village of Plinthine is certain during the Saite period, the boom in Ptolemaic occupation is attested by the size of the village dating from this period. The entire region was intensively exploited by the new settlers, following the arrival of Greek immigrants after Alexander's conquest (Boussac and Redon 2022).

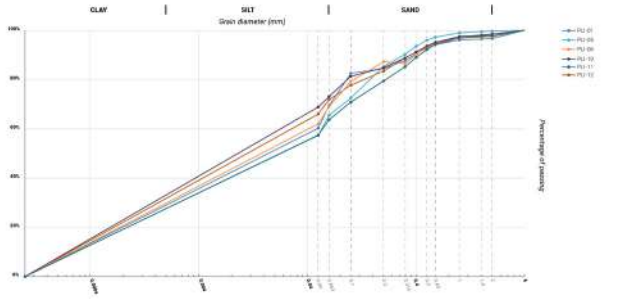

Figure 10: Superposition of the granulometric curves of PLI-012 (Ptolemaic period) and Saite 1 group.
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During this year's archaeological season, 8 new samples of bricks, mortar and plaster were taken in this sector. The field tests carried out and the forthcoming laboratory tests should provide a better understanding of the use of earthen resources at that time, and of any issues that may have been linked to it.

CONCLUSION

Although the first studies of earthen building materials at Plinthine are still limited, they have involved 13 samples from over a wide period ranging from the New Kingdom to the Ptolemaic period. Most of these were taken from Saite structures, and they have already led to the identification of important information about the use of earthen materials in each of these periods.

Our work, using both field data (on raw and manufactured materials) and laboratory analyses, has shown that for each period and type of occupation of the Plinthine site, the nature of the raw materials used varied according to the needs and challenges of the inhabitants.

In the New Kingdom, phases of occupation and abandonment seem to follow one another. The raw material used seems to be that which lay directly under the feet of the occupants: either recovered from previous installations or naturally regenerated by wind action. The forthcoming analysis of more samples from this period should enable us to understand if this use of local soil was only an isolated example or in fact common practice.

The Saite period is marked by major developments. The soil used for Saite constructions seems to be a blend, with the addition of large fragments of crushed shell and clay from nearby swampy areas. We now need to understand the logic behind this blend: was it related to the construction of large infrastructures? Was it linked to a political desire or the builder's knowledge of their environment?

Finally, in the Ptolemaic period, the growing need for building materials seems to have led to a significant amount of activity involving the recovery of materials used in earlier periods. This would also explain the variety of earths that have been studied to date.

These results are obviously preliminary; in 2023 18 new samples (bricks, mortar, plaster and clay) were taken from the New Kingdom and Ptolemaic sectors that are currently being excavated. The data collected in the field and their analysis in the laboratory next year should enable us to complete these initial research hypotheses.

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EVALUATION TABLE OF ANCIENT EARTHEN BUILDING MATERIALS

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SUMMARY

Across different eras and geographical locations, earthen building materials have been produced and applied in different ways, demonstrating the diversity of soil types and local stabilization techniques. The purpose of this study is to provide readers with a convenient tool for evaluating ancient earthen materials using a table. The purpose of this kind of reorganization is to provide a useful guide for earthen builders, material researchers, and heritage protection professionals. Having sections that are based on the number of settlements on the map, their names, geographical locations, structural functions, and compositions of samples makes it easy to locate settlements, soil mineralogy, and additives. Based on a research conducted in 2019, this study reorganizes the data collected on ancient building materials of Anatolia. The purpose of this study is to suggest the preparation of a database for earthen building materials throughout the world, including earthen architectural sites that are considered world heritage sites. Due to the structure and organization of the proposed documentation, this important past knowledge would not be lost to future generations and would be disseminated locally among earthen architecture builders.

INTRODUCTION

Earthen building materials have been produced and applied in a variety of ways throughout history, reflecting different soil types and local stabilization techniques. In spite of the fact that many geographical regions have a rich cultural and technical heritage, economic prosperity and prejudice have led to the collapse of earthen structures and the rapid transition to concrete structures[1]. As synthetic materials are increasingly being implicated in building-related diseases, and as Institute of Building Biology (IBN)-led research becomes more prevalent, earthen materials are once again gaining traction. In IBN's evaluation of building materials, earthen materials ranked highest in terms of their environmental and health benefits[2]. This popularity has led to new research studies into soil improvement and stabilization. As part of the research in 2019, the author reviewed past experiments conducted on soil improvement and stabilization since the 1960s. These experiments revealed that earthen building materials were typically treated with synthetic additives that would have led to their loss of valuable properties, which IBN highly values[3]. The lack of consideration given to sustainable ancient soil stabilization methods is surprising. Studying archaeological material culture enables researchers to gain detailed information about the production and use of building materials in ancient times.

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1. Kurtul 2009.
2. IBN 2023
3. Kurtul Vacek 2019.

Therefore the author of the present study collected and evaluated the research results of the earthen building materials belonging to 8 ancient settlements, including Aktopraklık, Güvercinkayası, Aşıklıhöyük, Arslantepe, Çatalhöyük, Barcın Höyük Ulucak Höyük and Yumuktepe[4]. Furthermore, earthen building material samples were examined by the author at the micro level from the ancient settlements of Küllüoba and Daskyleion. The results from all the studies contributed to the preparation of the table used for assessing and documenting the soil improvement and stabilization methods[5]. For this study a review of an evaluation table is conducted with the intention of expanding the ancient earthen building material recipes from Anatolia to Nile Valley. A table of this kind indicates an initial step toward democratizing scientific work for the benefit of all through the spread of earthen building knowledge.

1. METHODS

In the section 'Archaeological Character' of the book on soil building material, Van Beek explains how sensitive it is as a result of moisture penetrating the ancient soil blocks, which had been buried for many centuries. Further, he states that it is very difficult to remove the adobe blocks without breaking them and that it is even difficult to detect them during excavation[6]. As a result, all scientific studies on the material that enable information transfer through this challenging process are very valuable. In this regard, the literature review is conducted as a means of collecting information that is then organized into a table for ancient earthen building materials. Only the results of analyses conducted in a laboratory environment were included in the table as scientific data within the scope of the study. The table does not include macro analyses of earthen building materials samples found at archaeological sites.

As part of the author's 2019 research, samples of Küllüoba and Daskyleion earthen building materials were analyzed on a micro scale in a laboratory environment. First, permission was obtained from the museum directorates affiliated with the archaeological sites to bring the selected materials to the laboratory. During the laboratory investigation, soil material samples were analyzed visually, documenting the visual evidence and grouping the samples according to their visual similarity, using simple chemistry to identify the compounds present within a sample, determining salt, protein, fat, organic matter content, testing for physical and mechanical properties, thin sectioning, XRD analysis, and XRF analysis were performed to determine their content and characteristics.[7, 8]. Istanbul Technical University (ITU)'s Faculty of Architecture's building materials laboratory provided assistance with visual analysis, simple chemistry analysis, and physical-mechanical property tests. In addition, Fatih Sultan Mehmet Foundation University's Cultural Heritage Conservation, Application and Research Center (KURAM) laboratory provided advanced technical analysis support.

To facilitate the transfer of surveyed knowledge (see Part 2) and the results of the laboratory examinations (see Part 3), ancient samples have been mapped and the necessary data has been organized into a table for easy evaluation by earthen builders, material researchers, and heritage protection professionals (see Tab. 1).

2. EARTHEN BUILDING MATERIALS FROM ANCIENT ANATOLIA

Based on the literature review survey, it was discovered that earthen building material samples have been examined at a micro level only at eight excavation sites in Anatolia[9]. Below is a list of ancient sites along with their location, dates, and research that has been conducted on the material.

2.1. AKTOPRAKLIK

The ancient city lies in the province of Bursa. Between the second half of the 7th millennium BC and the first half of the 6th millennium BC, it was continuously inhabited[10]. As mentioned by Karul, the wattle-and-daub huts in Aktopraklik settlement were replaced by mudbrick buildings during the Early Chalcolithic Period, and an organized society developed.

The resulting data from Aktopraklık have been evaluated and entered into the table of ancient earthen building materials (Tab. 1) based on the analysis of earthen building samples dating back to 5700-5600 BC (Early Chalcolithic Period) by Noei[11].

2.2. GÜVERCINKAYASI

The settlement dates to the Middle Chalcolithic period (5200-4750 BC) and is situated along the Melendiz water bank in Aksaray Province, near Çatalsu Village.

In the Güvercinkayası settlement, earthen building materials have been used since the Neolithic period, when the most primitive dwellings were constructed. According to the earliest examples, pise is built in Güvercinkayası settlement by compressing mud mixed with sufficient water into pellets and using them as building materials[12, 13].

The resulting data from Güvercinkayası have been evaluated and entered into the table of ancient earthen building materials (Tab. 1) based on the analysis of earthen building samples by Noei[14, 15].

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4. Ibid.
5. Ibid.
6. Van Beek 2007.
7. Kurtul Vacek 2019.
8. Kuram 2019.
9. Kurtul Vacek 2019.
10. Karul 2013.
11. Noeİ 2017.
12. Noeİ 2011.
13. Coockson 2010.
14. Noeİ 2011.
15. Noeİ 2017.

2.3. AŞIKLIHÖYÜK

Located in Aksaray province, Central Anatolia, between the Hasan and Melendiz mountains, this settlement was occupied between 8500 and 7300 BC.

Despite being a rocky settlement, soil was the main building material, although construction techniques changed over the course of the settlement's existence.

The resulting data from Aşıklıhöyük have been evaluated and entered into the table of ancient earthen building materials (Tab. 1) based on the analysis of earthen building samples by Uzdurum and Mentzer[16], Noei[17] and Duru[18].

2.4. ARSLANTEPE

The mound was inhabited from 5000 BC until the 11th century AD in the Orduzu town of Malatya.

The resulting data from Arslantepe have been evaluated and entered into the table of ancient earthen building materials (Tab. 1) based on the analysis of earthen building samples by Liberotti[19], Liberotti and Quaresima[20], Alvaro et al.[21], Noei[22].

2.5 ÇATALHÖYÜK

The ancient city lies about 10 kilometers east of Umra District in Konya Province. There is evidence of settlement dating back to 5500 BC.

Çatalhöyük provides valuable information about Neolithic earth construction techniques. Numerous studies have been conducted on the analysis and conservation of the plasters found at Çatalhöyük. In order to determine the appropriate conservation technique, the soil mineralogy of the finds was studied.

The resulting data from Çatalhöyük have been evaluated and entered into the table of ancient earthen building materials (Tab. 1) based on the analysis of earthen building samples by Love[23], Noei[24] and Kopelson[25].

2.6. BARCINHÖYÜK

Located in the Yenişehir Plain, east of Bursa, the site was occupied between 6600 and 6000 BC.

The resulting data from Çatalhöyük have been evaluated and entered into the table of ancient earthen building materials (Tab. 1) based on the analysis of earthen building samples by Noei[26].

2.7. ULUCAKHÖYÜK

The site is located 7 km east of Izmir city center and Bornova District. In the vicinity of the Gediz River and the Nif Stream, it is situated on a fertile plain. Between 1997 and 2012, excavations revealed that the mound was occupied intermittently between the Aceramic Neolithic Period (7500 BC) and the Late Roman-Byzantine Period.

The resulting data from Çatalhöyük have been evaluated and entered into the table of ancient earthen building materials (Tab. 1) based on the analysis of earthen building samples by Noei[27].

2.8. YUMUKTEPE

The archaeological site Yumuktepe, which has been continuously inhabited since the Neolithic Age, is situated about one kilometer northwest of Mersin's city center in the Demirtaş Quarter.

The resulting data from Çatalhöyük have been evaluated and entered into the table of ancient earthen building materials (Tab. 1) based on the analysis of earthen building samples by Noei[28].

3. ADDITIONS

Following a literature review, the author[29] identified earthen building materials from eight archaeological sites, Aktopraklık, Güvercinkayası, Aşıklıhöyük, Arslantepe, Çatalhöyük, Barcınhöyük, Ulucakhöyük, Yumuktepe, which were analyzed in a laboratory environment and represent the Neolithic and Chalcolithic periods. These two periods are generally associated with ancient earthen building architecture. However, earthenware from later periods may also contain important information regarding content and deserves further investigation.

In 2019, the author conducted an examination of earthen building materials from two archaeological sites, Küllüoba and Daskyleion, dating from the 3rd to the middle of the 1st millennium BC. It is intended to provide information about the content of earthen building materials from the Bronze and Iron Ages, which are later periods than previously studied sites, in addition to adding to the Table 1 new regional and periodic data.

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[16] Uzdurum, Mentzer 2018.

[17] Noei 2017.

[18] Duru 2013.

[19] Liberotti 2012.

[20] Liberotti, Quaresima 2012.

[21] Alvaro *et al.* 2008.

[22] Noei 2017.

[23] Love 2012.

[24] Noei 2017.

[25] Kopelson 1996.

[26] Noei 2017.

[27] Ibid.

[28] Ibid.

[29] Kurtul Vacek 2019.

3.1. A BRONZE AGE SETTLEMENT: KÜLLÜOBA

Küllüoba, which has been identified as a Bronze Age settlement (3000-1200 BC), is located 35 km southeast of Eskisehir, 15 km northeast of Seyitgazi district, and 1.3 km south of Yenikent Village. The ancient settlement provides a wide source of information for academic studies on the Bronze Age architecture of Western Anatolia.

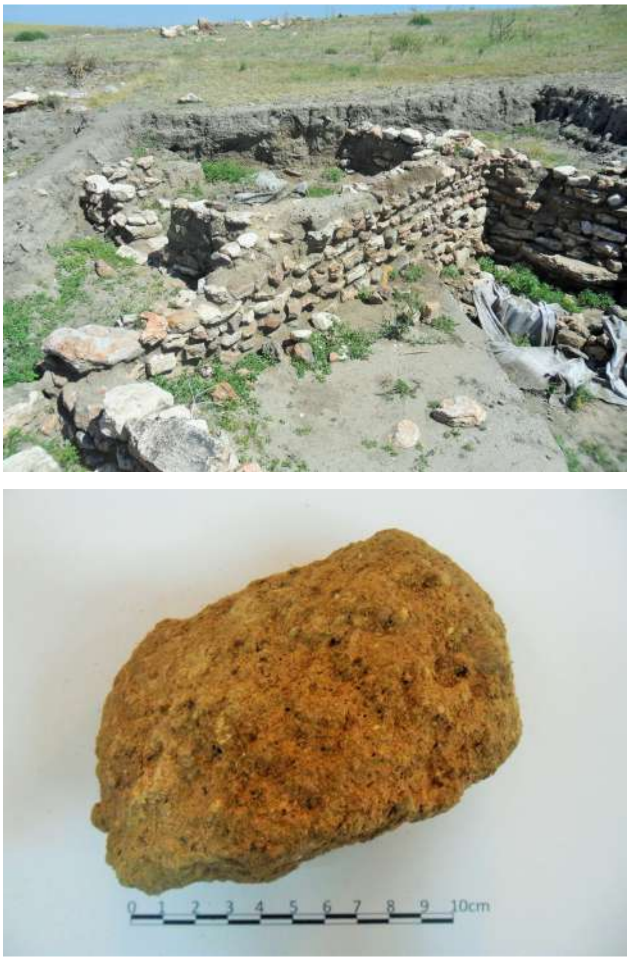

Figure 1: Küllüoba, Sample no.14.
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The author collected and analyzed in the laboratory 19 earthen building material samples from Küllüoba for the 2019 study. The resulting data from Küllüoba have been evaluated and entered into the table of ancient earthen building materials (Tab. 1) based on the analysis of earthen building samples by Kurtul Vacek[30].

3.2. AN IRON AGE SETTLEMENT: DASKYLEION

Daskyleion is a site that has been documented as an Iron Age settlement, and it is located near Ergili Village, part of the Bandarma District of Balkesir Province, and close to the southeast corner of Lake Manyas[31]. It is known as an important Satrapal centre, however excavations have revealed that it also contains constructions associated with the Phrygian, Lydian, Hellenistic, and Byzantine periods[32].

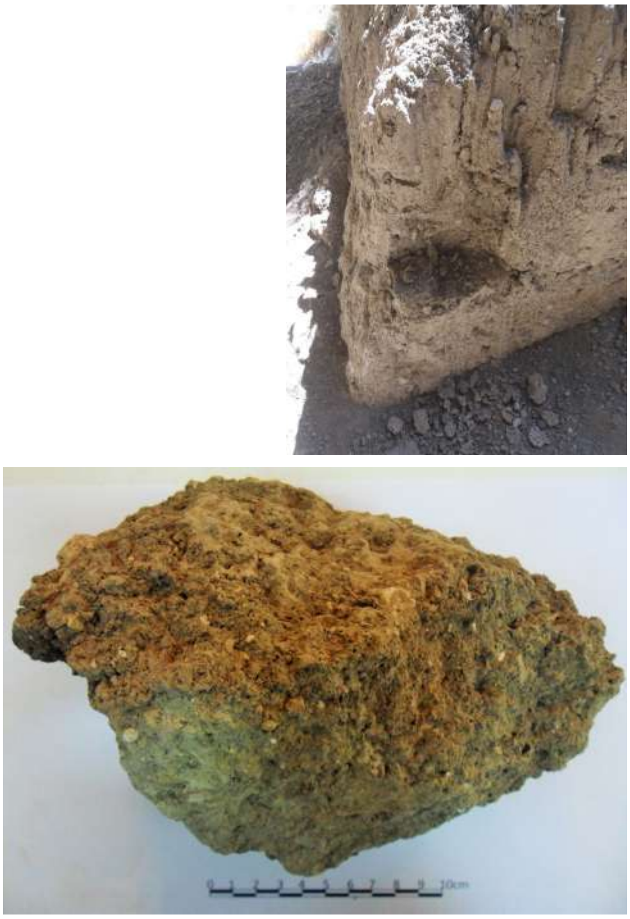

Figure 2: In-situ picture of sample no.24 in Daskyleion, Sample no. 24.
© F. P. Kurtul-Vacek

The author collected 13 earthen building material samples from the archaeological site of Daskyleion in 2019 and analyzed them in the laboratory. The resulting data from Daskyleion have been evaluated and entered into the table of ancient earthen building materials (Tab. 1) based on the analysis of earthen building samples by Kurtul Vacek[33].

3.3. RESULTS OF THE 2019 RESEARCH

Main result of the research on the soil material samples of the ancient cities of Küllüoba and Daskyleion showed that in ancient times people knew the properties of soil and its benefits and disadvantages and used improvement-stabilization techniques accordingly.

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[30] Ibid.

[31] Sevİn 2007.

[32] Bakİr 2011.

[33] Kurtul Vacek 2019.

As a result of the research on Daskyleion materials, sample no.24 (see Fig. 2) has been identified as one example with interesting physical-mechanical property results containing additives used for stabilization. The use of flax fibre as an additive in the block sample no.24 prepared for the construction of the fortification walls in Daskyleion, long before the contribution of flax fibre as an important composite material component has been discussed in academic studies[34] shows that the old knowledge has the potential to shed light on the sustainability of modern soil material research.

The research has been furthered by a study on flax in earthen building materials, which is aimed at determining how flax can be adapted to be used as an earthen building component in the Central European construction industry, where flax is currently the primary production region.

4. EVALUATION TABLE OF ANCIENT EARTHEN BUILDING MATERIALS

This table is intended to provide an easy-to-use reference for evaluating ancient earthen materials. Sections are categorized by settlement number on the map, name, location, period of earthen building samples examined, structural functions of the buildings, and soil mineralogy and additives (see Figs. 3-4). Samples belonging to different periods are distinguished. The table below lists the additives used within the Improvement-Stabilization Method. (-) sign indicates that the appropriate explanation was not found in the source.

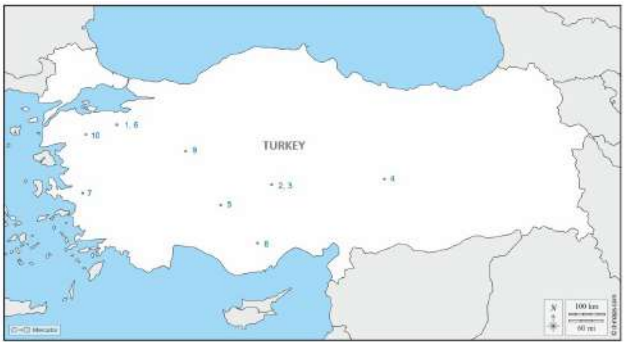

Figure 3: Geographical representation of the archeological sites of Tab.1 on map of Turkey (1-Aktopraklık, 2-Güvercinkayası, 3-Aşıklıhöyük, 4-Arslantepe Höyüğü, 5-Çatalhöyük, 6-Barcınhöyük, 7-Ulucakhöyük, 8-Yumuktepe, 9-Küllüoba, 10-Daskyleion)
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Based on the soil mineralogy of a specific geographical location, the user can gain an understanding of what was used to stabilize soils in ancient times, as well as compare it with other periods and ancient locations.

Data provided by the person filling out the table should be a concise summary of the laboratory findings as explained in the scientific report. It is intended that this table be accessible and understandable to anyone interested in the ancient approach to soil stabilization.

DISCUSSION

Besides Table of Ancient Earthen Building Materials, prepared by the author of this paper, there are several other tables listing results of the macro analysis of ancient earthen building materials in Turkey[35]. The macro analysis is usually carried out on the site, not in a laboratory, using visual analysis methods. One example of this is Fidan's analysis of mudbrick materials in Küllüoba based on their colors and characteristics on the site and a table presenting the results[36]. Based on similarly macro-based assessments, Dede developed a typological classification study for earthen building materials found on the site of the ancient settlement of Aşıklı Höyük[37]. Based on the study of Dede, eight types of adobe soils were identified and the types of additives used to stabilize them were listed in a table. In the section on additives, these analyses are provided as estimates since they are not the results of laboratory analysis but only visual assessments. A different example is the extensive research undertaken on the ancient earthen building material of Arslantepe, which resulted in different tables containing the results of the chemical and physical analyses[38]. The Arslantepe soil blocks have been the subject of numerous scientific publications, but the results have never been accessible to local builders. In the study of ancient earthen building materials, Correas-Amador has developed an interactive tool that can be used to document, analyze, and interpret ancient Egyptian domestic mudbrick architecture[39]. Despite the fact that a tool of this sort would simplify the documentation of mudbrick heritage for professionals, it is different from the tool described in this paper in terms of its purpose, audience, and issue of additives.

However, this paper's table tool is the outcome of laboratory research after an evaluation process to form a simple interpretation of listing. The author of this article is unaware of any other efforts to document earthen building material ingredients that are comparable to those in the Table of Ancient Earthen Building Materials.

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[34] See e.g. Garkhail et al. (2000) who created a composite composition using flax fibres and propylene (PP). Hardness, tensile and Charpy impact tests were applied to the prepared composite samples. By examining the values obtained from the experiments, they concluded that composites reinforced by natural fibre are attractive for low-cost engineering applications. Researchers state that flax fibre can compete with glass fibre, especially when high hardness per mm^2 is desired.
According to the IBN's Building Materials Table, glass wool should be evaluated with 1.2 points while linen gets 2.3 points, which has a higher value in ecological and health protection as building material (IBN).

[35] Kurtul Vacek 2019.

[36] Fidan 2011.

[37] Dede 1997.

[38] Alvaro *et al.* 2008.

[39] Correas-Amador 2013.

MAP NO.	ANCIENT SETTLEMENT	GEOGRAPHIC LOCATION	AGE OF THE SAMPLE[1]		STRUCTURAL FUNCTION	COMPOSITION	
						SOIL MINERALOGY	ADDITIVES[2, 3]
1	AKTOPRAKLIK	Bursa 40° 11' 30" N 29° 3' 40" E	5700-5600 BC		Earthen block	Rich calcareous and clay soil Soil with high phosphorus content Small[4] amount of ash	Land-based aggregate, animal fertilizer additives In some layers there is rubble from the previous layer (only in these layers shards of pottery were added to the mortar) No organic additives
2	GÜVERCİNKAYASI	Aksaray 38°22'21.18" N 34°1'31.33" E	a[5]	5200-4750 BC	Earthen block	Tuff-quality minerals High percentage of lime	-[6]
					Wall plaster	Montmorillonite clay mineral Chlorite clay mineral	-
			b[7]	5200-4750 BC	General[8]	-	Secondary use, animal waste, rock fragments of volcanic origin, river sand with rounded corners, limestone fragments, terracotta fragments.
					Wall plaster	Montmorillonite clay mineral (binder)	There is animal manure, clay, both round and angular aggregates.
					Earthen block	Lime (binder)	There are small sized, round aggregates, angular gravel of terrestrial nature, straw, lime from the stream side.
					Roof	Lime (binder)	-
					Floor	Lime (binder)	Only in the floor mortar there is an admixture of tuff crushed stone.
					Roof and floor plaster	-	There's more lime than in all the samples. Organic additives are almost non-existent.
3	AŞIKLIHÖYÜK	Aksaray 38°22'21.18" N 34°1'31.33" E	a[9]	8th millennium BC and 9th millennium	Earthen block	Types of rocks of volcanic origin Gypsum, basalt, feldspar, quartz, tuff, volcanic glass	Hedgerow, charcoal, ash, dung (8th millennium), bark, large/small plants (9th millennium)
					Joint mortar	-	There are more aggregates (8th millennium) than earth blocks. There is recycled building material.
			b[10]	8350-8050 BC 8100-7740 BC 7850-7300 BC	Earthen block	Minerals of volcanic origin High amounts of calcium (in layer 4) Gypsum (in layers 2 and 3) Phosphorus (in layer 3)	Secondary use of rubble, husk, animal manure (in layer 3), terracotta pieces, plaster
			c[11]	8th millennium BC and 9th millennium	Earthen block	Calcite (in layers 3 and 4)	Animal feces, grain inclusions, mineral additives, recycled building material contribution.
4	ARSLANTEPE HÖYÜĞÜ	Malatya 38°21'0.65"N 38°19'0.01"E	a[12]	3800-3350 BC 3350-3000 BC	Earthen block	Calcite, quartz, plagioclase,phyllosilicate, gypsum and/or dolomite.	There are pottery shards, animal bone fragments and plant material
					Plaster	Same mixture as earthen block. But the calcium content is slightly higher. Iron content ranging from 4.5-11.3%.	_
			b[13]	3800-3350 BC 3350-3000 BC 2900-2800 BC 2500-2000 BC 1750-1600 BC 1600-1200 BC 1100-712 BC	Earthen block	Calcite, quartz, plagioclase, phyllosilicate, gypsum and/or dolomite.	Widely used plant additives.
					Plaster – 1st part	-	Plant and charcoal particles.
					Plaster – 2nd part	-	Round sand particles
					Plaster – 3rd prt	Purified clay	No additives
			c[14]	4th millennium BC	Earthen block	Aluminum, magnesium, iron, silicate, chlorine, potassium, calcium	There are plant additives
			d[15]	3900-3400 BC	Earthen block	Soluble salt (due to long periods of no excavation), magnesium carbonate	No gypsum, no secondary use, no animal waste There is clod Aggregates are angular, homogeneous and terrestrial
5	ÇATALHÖYÜK	Konya 37°52'16.86"N 32°29'4.7"E	a[16]	7400-6000 BC	Earthen block	Quartz, feldspar, calcite, chert, basalt, gypsum and granite particles	Mica, hornblende, garnet, pumice, bone, coal particles
			b[17]	6800-6700 BC 6700-6600 BC 6600-6500 BC 6500-6400 BC	Earthen block	Iron oxide, magnesium carbonate (Dolomite)	Plaster (in some examples) No organic additives[18] No animal feces The rubble of old mortars was used
			c[19]	Early Neolithic	Wall plaster	Clay soil High amounts of calcium carbonate Sulfate in all samples, small amounts of chloride	Small additions of organic matter
					Relief plaster		Small additions of organic matter
					Earthen block		High additions of organic matter
6	BARCINHÖYÜK	Bursa 40° 11' 30" N 29° 3' 40" E	6450-6350 BC		Earthen block	Small amounts of lime, kaolinite minerals High amounts of iron oxide	No organic additives There is secondary use There is the use of ash and animal manure
7	ULUCAKHÖYÜK	İzmir 38°24'45.83"N, 27°8'18.17"E	6800-6600 BC 6200-6100 BC 5840-5720 BC 5630-5530 BC		Earthen block	High amounts of iron oxide	There is a straw-like organic additive and an animal additive. No ash and no secondary use.
					Plaster	-	Gypsum
8	YUMUKTEPE	Mersin 36° 48' 43.5744" N 34° 38' 29.3316" E	5500 BC 4600-4500 BC		Earthen block	Lime	No animal waste and no secondary use. There are finds of straw, ash and cinders.
					Floor	Lime binder sludge	-
					Joint mortar	Low lime content. Clay sized particles are high.	Finer aggregate additives
9	KÜLLÜOBA	Eskişehir 39° 45' 58.2948" N 30° 31' 36.1704" E	2650 BC 2450 BC 2550 BC		Earthen block	Fine-grained quartz, feldspar, carbonated aggregate (limestone) and to a lesser extent mica minerals	-
					Plaster	Coarse-grained quartz, feldspar, carbonated aggregate (limestone) and to a lesser extent mica minerals	Straw[20]
					Joint mortar	Fine-medium grained quartz, feldspar, carbonated aggregate (limestone) and to a lesser extent mica minerals	-
10	DASKYLEION	Balıkesir 39° 19' 40.5228" N 26° 43' 37.1640" E	Phrygian period (8th and 7th century BC) 6th century BC 6th century BC-5th century BC 530 BC 4th century BC		Earthen block	Fine-grained quartz, feldspar, carbonated aggregate (limestone) and to a lesser extent mica minerals	Straw Flax tow[21]
					Plaster	Fine-grained quartz, feldspar, carbonated aggregate (limestone) and to a lesser extent mica minerals	Plant fiber additives in general Flax tow
					Joint mortar	Fine-grained quartz, feldspar, carbonated aggregate (limestone) and to a lesser extent mica minerals	Flax tow

Table 1: Table of ancient earthen building materials (the references given for Sections 2 and 3 are valid also for this table).
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1. The different periods to which the different samples belong are indicated.
2. Additives used within the scope of the Improvement-Stabilization Method.
3. The presence of additives is not quantified.
4. Adverbs of quantity (e.g. "less" and "more") are used as in the source.
5. Noeİ 2011.
6. The relevant explanation is not available in the source.
7. Noeİ 2017.
8. Common features of almost all examples.
9. Uzdurum, Mentzer 2018.
10. Noeİ 2017.
11. Duru 2013.
12. Lİberottİ 2012.
13. Lİberottİ, quaresİma 2012.
14. Alvaro et al. 2008.
15. Noeİ 2017.
16. Love 2012.
17. Noeİ 2017.
18. Like husk and straw.
19. Kopelson 1996.
20. Plants commonly used for hay include rye, meadow grass, various grass species. Various types of clover from legumes are also used. Stalk straw, whose seeds are separated and the remaining stalks are dried and have low nutritional value, is used as bedding for animals. The straw used as an additive to adobe mortar is the straw defined above as stalk straw, which is agricultural waste whose seeds are removed and dried (Akkas 2011).
21. Fiber.

CONCLUSION

In this study, the table made an initial contribution to the democratization of scientific work through the dissemination of earthen building knowledge. It is imperative that ancient sustainable knowledge from ancient civilizations be rediscovered in light of the current climate crisis and the need for sustainability in the construction industry. Stabilization of soil for the construction of healthy earthen buildings is the result of centuries of study that connects human beings across cultures for a better understanding of sustainability.

It is suggested that such a database be prepared for earthen building materials in different parts of the world, including earthen architectural sites recognized as world heritage sites. As the database is expected to be expanded across a wide range of different geographies of the world, Nile's Earth data from the ANR project would be the second such database after Anatolia's heritage.

As a result of the structure and organization of the proposed documentation, this crucial past knowledge would not be lost to future generations and would be disseminated among earthen architecture builders locally. Moreover, a database of earthen building material recipes would contribute to the current research on the development of sustainable earthen building materials. In conclusion, revitalizing local earthen construction techniques would prevent the eventual abandonment of earthen building materials and would allow a focus to be placed back on a vernacular architectural identity as well as on the development of a healthy living environment.

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STRUCTURAL ASSESSMENT OF MOSQUE BUILDING IN OLD DONGOLA, SUDAN

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SUMMARY

The paper presents the structure-oriented results of the initial stage of the revitalisation project (Baraka project) of the mosque building in Old Dongola, in northern Sudan. The present state of knowledge about the building allows us to state that since the 9th century, for over 450 years, it served as a throne hall and church built and used by the kings of Makuria, the kingdom in Nubia, then, in 1317 CE, it was transformed into a mosque. Nowadays, some parts of the building are closed to the public and require thorough structural interventions to guarantee safety for further archaeological work and future service as a mosque and museum of local culture. The structural assessment presented in the article includes the analysis of structural materials (focusing on adobe masonry structure), their mechanical and physical characteristics and composition, and the identification of the main structural elements and their threats. Moreover, the main guidelines for the preparation of the final stage of the revitalisation project regarding building strengthening and repairs are developed within the paper.

INTRODUCTION

Detailed diagnostics must precede the maintenance, strengthening, and reconstruction of historic structures. It should, as it is made in the case of Mosque in Old Dongola, consist of identifying materials, technologies, and techniques for constructing a historic building. As a result of the pursuit for better performance, modern structural materials, techniques, and technologies are widely studied and described. In many cases of ancient buildings, we are concerned with antique techniques and technologies that are not used today[1] [2]. Although historical structures are typically composed of simple elements, overall load distribution, and static schemes may not be obvious to modern engineers. A proper understanding of ancient structures is even more complicated due to the historical evolution of buildings. During the centuries of service Mosque building, was repeatedly repaired and rebuilt, which makes it difficult to interpret the original engineering concept. Taking it into consideration, an essential part of historical building diagnosis is oriented on the identification of structural elements and their characteristics. In the case of masonry structures (which are common in the Mosque in Old Dongola), it is important to analyse masonry elements, for materials, shape, and physical and mechanical parameters; mortar, for composition and physical and mechanical parameters; and bound scheme (arrangement of masonry elements in structure).

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1. Terlikowski 2014
2. Sobczyńska 2021

The article presents a preliminary diagnosis of a historic mosque, located in Old Dongola, northern Sudan (Fig. 1). The research is part of a revitalization project - the Baraka Project. The aim of this paper is a presentation of a preliminary phase of the ongoing diagnostic process. The research methodology presented in this paper consists of following steps: analysis of the building's structural elements focused on adobe masonry structure, initial assessment of structural elements, and basic guidelines for the development of building strengthening and repairs.

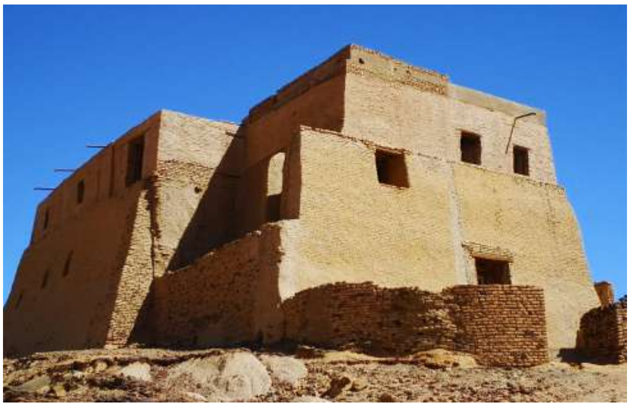

Figure 1: View of the mosque in Old Dongola.
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1. OVERVIEW OF THE BUILDING OF THE OLD DONGOLA MOSQUE

The present state of knowledge about the building allows us to state that since the 9th century, for over 450 years it served as a throne hall and church built and used by the kings of Makuria, the kingdom in Nubia. At the end of 13th century devastation of the building (especially of the south wall and some vaults in the southern quarter of the ground floor) due to the war between Makuria and Mamluk Egypt taking place – the wall was rebuilt, and the vaults were replaced with wooden ceiling. At this time the additional layer of external slope walls of approximately 6,5 m height was also added together with a flat roof. In 1317 CE the building was transformed into a mosque which resulted in a series of adaptations: the ground floor was partly filled (1,5 m above the original walking level), the interior window openings of the ground floor were converted into entrances, the original entrances to the building from the north and south were built up, external porticoes on the first floor were replaced with walls containing wide openings in the western corridor. The history of renovations ended with restorations made by Sheikh Sati Sawar el Dahab in the second half of the 18th century, restorations by Ahmed Helmi in years 1907-1908, and Sudan Antiquities Services and Museums in the years 1939,1940,1944,1945,1955 and later. In 1969 the mosque was shut down and archaeological exploration was enabled[3, 4, 5]. Nowadays, some parts of the building are closed to the public and require thorough structural interventions to guarantee safety for further archaeological work and future service as a mosque and museum of local culture.

The initial phase of the Baraka project is oriented toward the identification of the main structural threats and the development of temporary strengthening and stabilization techniques that allow further archaeological work on the ground floor. To identify each of the structural elements a detailed survey with a 3-d scanner was made. It is essential for the further development of the final design of the structural intervention and material strengthening [6].

The main structural members of the building are masonry walls and vaults, both composed of adobe with local insertions of fired bricks. External walls were strengthened in the past with a superficial layer of adobe increasing the total wall thickness on the ground floor to over 2 m. The roof over the building is composed of traditional mats made of palm branches covered with clay-based mortar supported by timber beams.

2. TECHNICAL CONDITION OF STRUCTURAL ELEMENTS

As was mentioned above the main structural members of the building are masonry walls and vaults, both composed of adobe (results of strength tests are described in Section 4) with local insertions of fired bricks. The overall condition of the interior walls is satisfactory, they mostly show sufficient load-bearing capacity. Local cracks and cavities are prevalent (Fig. 2). Damaged areas require structural intervention like repointing or stitching. In places that posed a threat of further material loss during nearby work, metallic protective nets were installed in the project's initial phase.

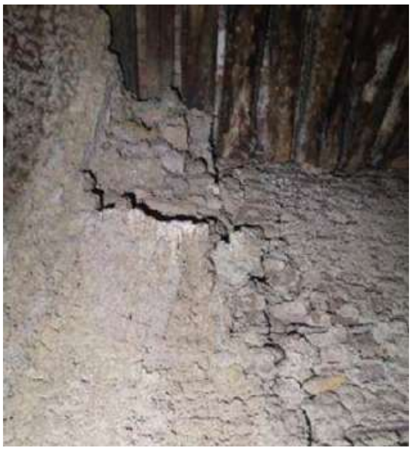

Figure 2: Room 1 western wall - visible cracks.
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3. Obłuski 2013
4. Fushiya 2023
5. Skarżyńska 2023
6. Terlikowski 2021

During the preliminary work, only one of the external walls required urgent protection due to a noticeable buckling of the central part, which became apparent as the excavation was carried out in its area (Fig. 3). Temporary protection was applied until its strengthening in the following season. After the analysis of this and other external walls, a key problem was noticed, i.e., the lack of bonding between successive layers of the wall built at different times, which leads to lower bearing capacity or even to its failure. Additionally, the inner part of the wall is based on a fill of loose material, which does not provide sufficient support for the wall. These problems will require urgent intervention in the coming seasons.

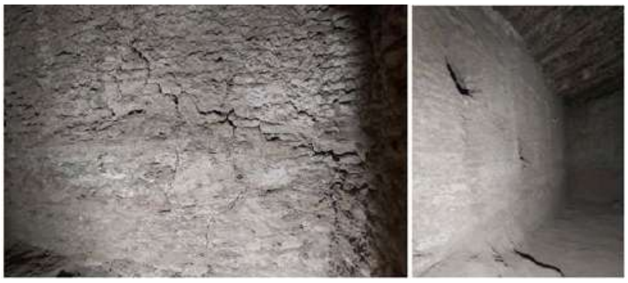

Figure 3: Southern wall in room 10 – deformation and visible cracks.
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Adobe vaults over the ground floor are partially collapsed and replaced with timber beams that support the floor of the upper floor (the technical condition of each of the beams will be assessed in the following seasons, and in case of unsatisfactory results, they will be replaced). Some losses of elements result in holes through the ceiling and create danger for communication on the upper floor and further destruction of vaults (Fig. 4).

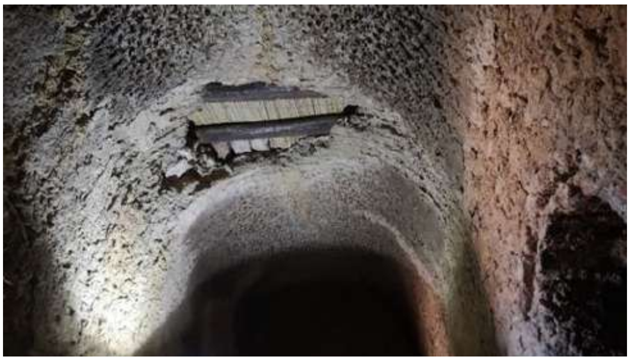

Figure 4: Room 2 - vault over the central part.
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The roof over the building is composed of traditional mats made of palm branches covered with clay-based mortar (sometimes also with bricks) supported by timber beams. Several losses of material are observed which result in water penetration to the building's interior, causing further degradation of structural materials. In combination with bat activity, it results in severe degradation of some of the timber elements (Fig. 5).

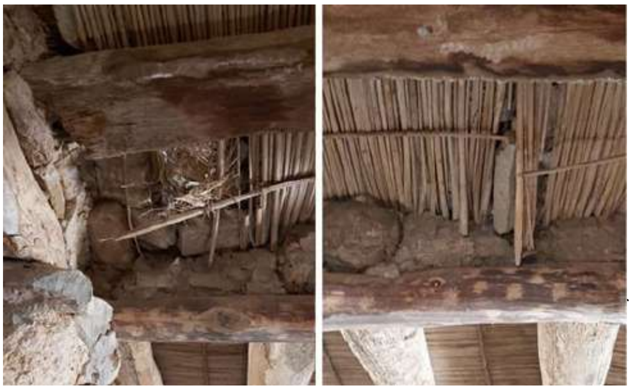

Figure 5: Damaged roofing in room 15.
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To monitor possible local deformation of the building or partial detachments of structural elements, five cracks were equipped with the monitoring system. The monitoring methodology is based on constant (or with the maximal possible frequency) measurement of the distance between two fixed points on two sides of the crack and the measurement of material temperature.

Literature studies revealed the possible explanation for significant sand deposits inside the building as stabilization for the external thrust of the wall's superficial layer that was formerly introduced. To verify this unlikely hypothesis, the monitoring of the relative horizontal wall displacement was applied. The monitoring methodology is based on daily measurement of the distance between two fixed points on two sides of each room (rooms 2, 4, 5, 6, 7, 10). Any significant changes should result in suspending further excavation and applying a struts system that provides building structural safety. The relative horizontal wall displacement monitoring should continue during the following seasons until the end of archaeological excavations of all studied rooms.

3. ADOBE ANALYSIS

Analysis of adobe was carried out on the samples extracted from remaining, partially collapsed vaults. It was possible to obtain parts of six adobe bricks, including one almost fully preserved (Fig. 6). Dimensions of full brick are approx. 33,3 cm x 17,5 cm x 7,5 cm and its weight – 5,09 kg. As is common, the shape is slightly irregular due to manual formation. The macroscopic analysis of the brick's cross-section reveals a high ratio of organic matter included in the masonry element, as well as fine grain size of aggregate. It was further approved with precise analysis.

The macroscopic analysis of the mortar (Fig. 7) leads to a similar conclusion as the one of brick – a high ratio of organic matter included in mortar, and mostly fine grain size of aggregate are observed. Detailed granulometric analysis revealed differences between aggregate used in bricks and mortar.

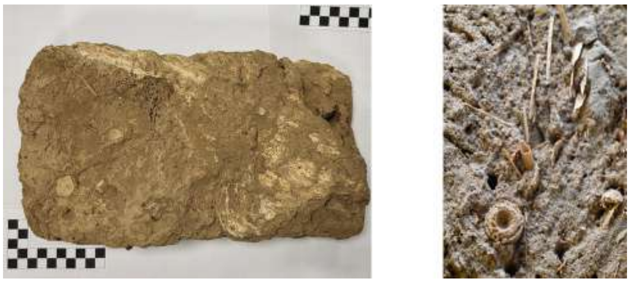

Figure 6: Adobe brick: full sample and macroscopic photography of a cross-section right.
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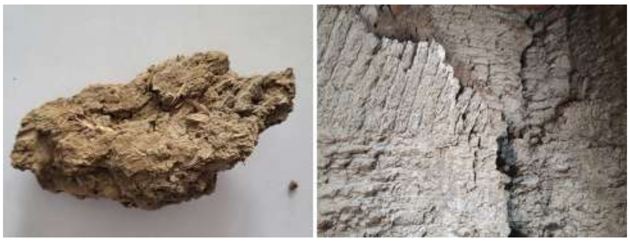

Figure 7: Mortar: sample and arrangement of brick and mortar in masonry vault and wall.
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Detailed analysis of the adobe was oriented on the determination of the main material components of bricks and mortar and the determination of the main mechanical characteristics. Components were examined with granulometric and ignition loss analyses. The first one, presents the detailed aggregate fractions distribution. The latter provides information on organic matter content.

The analysis of aggregate grain size distribution was carried out with the laser diffraction method with Horiba LA-300 device in the laboratory of the Faculty of Civil Engineering Warsaw University of Technology (Poland). The results (Fig. 8) show the distribution of fine-earth fraction (medium sand and smaller). The main fraction of aggregate in both, brick, and mortar, is silt. In the case of mortar, the silt content is, on average, more than 95% of the weight. In brick, more content of fine sand was observed (26%), but silt is still the main fine-earth fraction (73%). Based on the textural classification of soils, the main source material for brick and mortar was silt loam and silt.

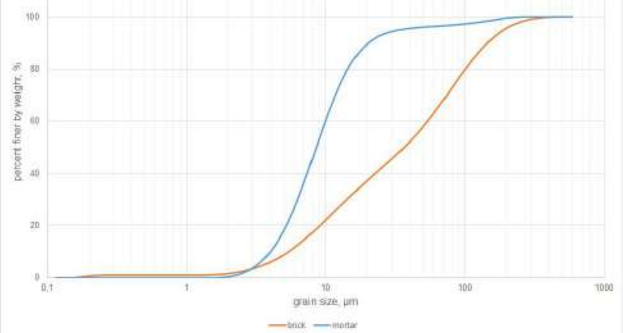

Figure 8: Fine-earth particle size distribution of tested brick and mortar.
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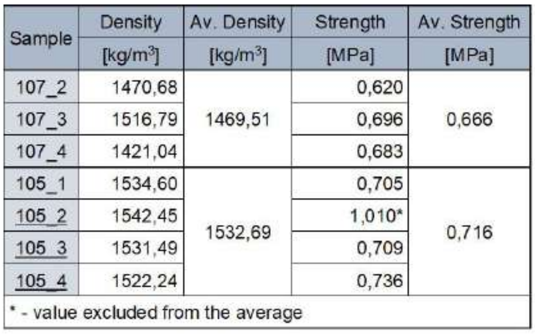
As was stated by macroscopic observation, another key component of bricks and mortar are straws and other biological matter. Its approximate amount was determined by loss on the ignition test. Due to the high heterogeneity of adobe, the results were wildly distributed. For bricks, the loss of ignition varies from 5% to 24%, and for mortar, it is 12,5% of weight. It must be noted that the results are approximated and should be interpreted as the maximum possible content of organic matter. Ignition loss may be also related to other reactions induced by high temperatures.

Compressive strength was analysed with destructive tests of samples cut from adobe bricks with universal testing machine Instron 5567 in the laboratory of the Faculty of Civil Engineering Warsaw University of Technology (Poland). Test specimens were extracted from two different bricks in a cubic shape of 50 mm approximate edge length. Compressive force at sample destruction during the test was based on the calculation of maximal compressive stresses. Small dimensions of samples could influence results due to the confinement of specimen surfaces by loading plates. Thus, results required conversion to normalize the compressive strength of masonry units that was based on code EN 772-1[7], by including the shape factor.
The fragile nature of the material resulted in difficulties in sample processing. During the cutting of bricks with a circular saw some intrusion of harder aggregate could result in a broken sample. Therefore, the influence of finishing was studied by preparing a set of samples with a thin layer of gypsum. The results are presented in the table in Fig. 9. The first part of the sample symbol relates to the sample extracted from the structure. Samples with finishing layers of gypsum are indicated in the table by underlining the sample symbol.



Sample	Density [kg/m³]	Av. Density [kg/m³]	Strength [MPa]	Av. Strength [MPa]
107_2	1470,68	1469,51	0,620	0,666
107_3	1516,79		0,696	
107_4	1421,04		0,683	
105_1	1534,60	1532,69	0,705	0,716
105_2	1542,45		1,010*	
105_3	1531,49		0,709	
105_4	1522,24		0,736	

* - value excluded from the average

Figure 9: Compressive strength of bricks.
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The average value of normalized compressive strength of adobe brick is 0,7 MPa. The addition of the gypsum layer has no significant results on test results. The observation of the destruction shape (Figs. 10-12) did not revile any characteristic pattern typical for materials with higher cohesion, such as fired bricks or concrete. Test results of materials with relatively low compressive strength and cohesion are particularly sensitive to the individual features of each sample. In the case of analysed material, it could be a local accumulation of aggregate or a specific orientation of straws. This is noticeable in the deviation from the average of sample 105_2, which is a result of heterogeneity of material than additional finishing.

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[7] Oliver 2008

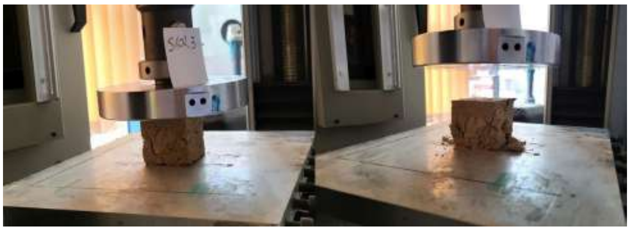

Figure 10: Adobe bricks sample 107_3 before and after compressive strength test.
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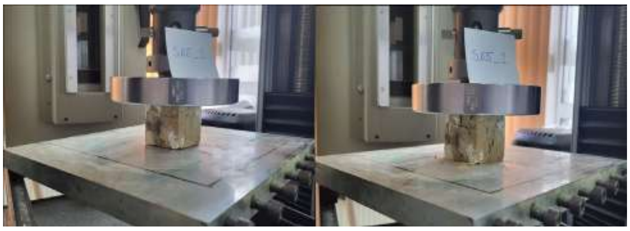

Figure 11: Adobe bricks sample 105_2 before and after compressive strength test.
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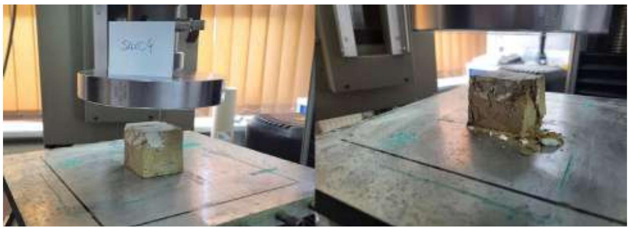

Figure 12: Adobe bricks sample 105_4 before and after compressive strength test.
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The presence of biological matter, such as straws, in the building material, creates an opportunity for a robust dating indicator for the C14 dating test. Samples extracted from crushed cubes of adobe bricks will allow us to confirm the date of the vault's erection.

4. BASIC GUIDELINES FOR THE DEVELOPMENT OF BUILDING STRENGTHENING AND REPAIRS

The guidelines for further strengthening design were developed based on the on-site analysis and laboratory tests. They could be divided into main sections concerning the type of structural elements: roof, ceilings (including adobe vaults), and walls. The guidelines should follow the general rules of conservation, such as preserving the authenticity of the building by limitation of intervention to the minimum necessary level[8]. As far as possible traditional and original technologies should be incorporated. Replacements should be done as an ultimate, only when any other solution is insufficient[9].

Immediate actions should be taken regarding the temporary roof repairs. The damages allowing the possible water penetration should be filled with clay-based mortar. In case of larger openings, the hole should be first protected with palm branches and covered with traditional clay mortar. The permanent treatment should be oriented on individual assessment of timber elements of the roof structure. Each member should be individually studied in the matter of possible use. It ought to be carefully examined for biological degradation of internal structure. If necessary, elements should be replaced with analogues, if possible, concerning the type of wood and processing. If timber elements are replaced, the roof finishing has to be recreated with the traditional technology – palm branches covered with clay mortar. The final shape of the roof should stay unchanged, but it should consider water drainage to avoid an accumulation of rainfall on the surface.

Recommendations for strengthening of inter-floor partitions depend on the location of the building and the structure. In the case of timber structures, beams should be examined and treated as analogical to roof structures. Assessing adobe vaults requires more detailed analysis, including numerical simulation, to determine the load capacity[10]. If the results reveal insufficient capacity, the strengthening method must be developed. It could be oriented on structural reinforcement of the vault, introduction of supplementary structural members that reduce the load transferred to the vault, or a mix of both. The proper strategy has to follow the main rules of authenticity and minimal intervention as far as possible. Reconstructions of vaults should be limited to the local losses of material. The collapsed vaults, substituted with timber beam floors, should not be recreated as a testimony of historical interventions in the building structure.

The main structural issue that needs to be addressed is the lack of cohesion between layers of adobe walls constructed separately in different periods of the building's history. Apart from local pathologies, adobe's relatively low compressive strength is sufficient for the building structure. Internal walls are mostly in good condition and require no or little structural interventions limited to local losses of substance. External walls require detailed analysis of internal structure, including determination of adobe layers and connection between them. Lack of cohesion needs to be assessed for structural safety. Some of the superficial layers of adobe resulting from former interventions may threaten structural safety. In such cases, dismantling may be considered, but it should be limited only when any other form of strengthening is unacceptable. The matter of the reintroduction of internal cohesion of the adobe layer is a subject of further studies.

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[8] Roca 2019
[9] Oliver 2008
[10] Lourenço 2022

The second important issue related to the adobe walls is the local lack of connection between formerly continuous structures. In such a situation, the separation reason should be determined and studied. The activeness of the source can be assessed with geometry and crack monitoring. If necessary, for example, in the case of the apse, where cracks allow the water penetration, after verification of the lack of activity of the source that caused the detachment, the continuity of partition should be reintroduced. As far as possible, original, or analogical technology should be used.

CONCLUSIONS

The paper presents the actual state of the structural assessment of the mosque built in Old Dongola, Sudan. It is the initial stage of the project Baraka: Revitalisation of the Oldest Preserved Sudanese Mosque at Old Dongola founded by ALIPH. The building's structure is detailed, including the main issues that must be addressed in the revitalisation process. The results of the laboratory tests given in the paper will be an essential input for further analysis, including numerical analysis, what is the main perspective, which may give us crucial information about the structural behaviour of the Mosque building. The basic guidelines for structural interventions were developed based on the on-site and laboratory tests. Some were already applied as an immediate intervention in the first season of the project execution. All the interventions developed based on the presented guidelines are limited by the current state of knowledge about the building. Any further discoveries, both during archaeological excavations and execution of structural interventions, may bring to light new circumstances that need to be considered and should result in the adaptation of further work.

ACKNOWLEDGMENTS

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FROM THE SILT TO THE SHALE CLAY, FROM THE VALLEY TO THE DESERT: THE MATERIAL TRANSFORMATIONS OF THE RED BRICK AND ITS SUPPLY CHAIN IN EGYPT AND SUDAN

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INTRODUCTION

Red brick is one of the most used and most visible building materials in Egypt and Sudan, especially in urban areas. Its production process is roughly the same in both countries : an earthen raw material is mixed with an organic one or with sand, the mixture is then moulded in bricks, dried in the open air, fired in a kiln and then delivered to the construction sites. However, a big difference separates both processes : the type of clay.

The Egyptian and the Sudanese producers are indeed not relying on the same earthen raw material. The Nile silt (*ṭin* - طين), deposited each summer on the banks of the river, is still used by the Sudanese ones whereas, in Egypt, this material has been replaced by the shale clay (*tefla* - طفلة), extracted from quarries in the mountainous peripheries of the Nile valley. This difference implies a series of discrepancies in the red brick itself, in its production line and in its whole supply chain, as I will try to evidence in this article.

Most of studies on this building material in Egypt and Sudan have focused on technical and environmental aspects, serving different purposes : demonstrating the air pollution caused by the brick kilns (Alam and Starr, 2009) ; proposing alternatives to the use of Nile silt in Sudan, like the use of pouzzolane (Ali, 2008) ; or highlighting the need to replace the red brick by other building materials like the compressed earth block or a straw-cement one (Mansour *et al.*, 2007). Following on from other analyses on building materials, either be it in urban geography (Choplin, 2020) or in ethno-archeology (Choimet, 2020), I argue that these technical issues can be integrated in a more global approach, at the scale of the supply chain and linking it to economic, social and geopolitical dimensions.

Then, this paper relies on a ten months qualitative fieldwork in both countries, between February 2020 and June 2022, conducted in the context of a PhD thesis in urban geography. I led informal and guided interviews with many different actors who play a part in the red brick supply chain (producers, workers, architects, engineers…). For this article, I will specifically focus on visits to factories and on interviews with the producers around Cairo and Khartoum, in order to describe and explain their use and practice of earthen materials. Where are they buying it ? Are there different qualities of clays and of bricks? What are the differences between Nile silt and shale clay in the production process?

I do not aim to find an alternative to the red brick or enhance its production process. I am rather trying to understand the whole production context, the relationship between red brick producers and public actors and the access to raw materials. By analyzing the shift, or the absence of shift from Nile silt to shale clay in the red brick production process, I argue that technical aspects are to be linked with economic, political and urban ones.

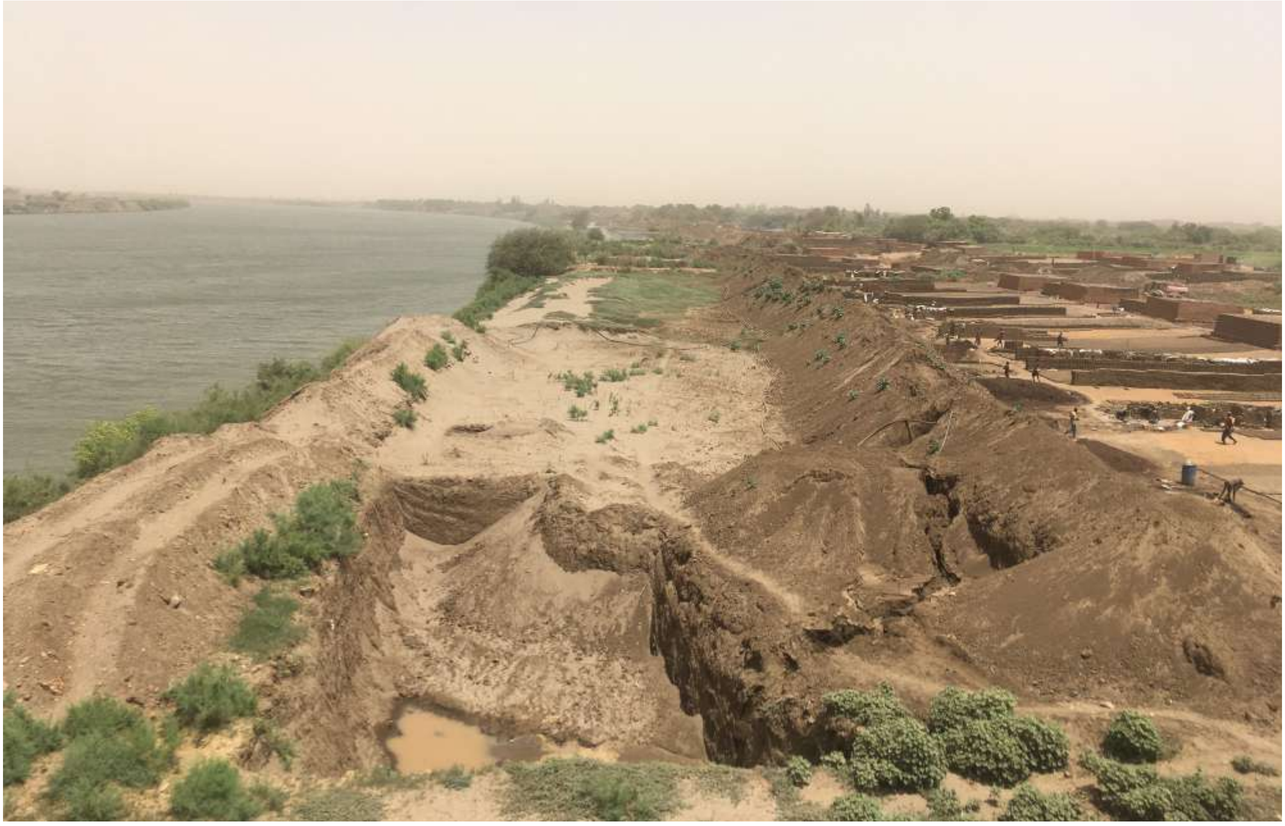

Figure 1: The red brick kilns concentrated along the Blue Nile in Soba (Khartoum).
© April 2021, C. Pérez-Houis

After describing the composition of the red bricks and the geography of their supply chains, I will come back on this shift from Nile silt to shale clay, which did happen in the 1990s in Egypt but didn't in Sudan until now. Finally, the paper will deal with the rising difficulties in the access to clay for producers, linking it with methodological issues.

1. THE DIFFERENT CLAYS EXPLOITED ALONG THE NILE

The Sudanese red brick is made of Nile silt. It comes from the erosion of a basalt bedrock in Ethiopia and is deposited by the floods on the river banks each rainy season, after being transported by the Blue Nile. According to an interview with an engineer at the Geological Research Authority in Khartoum (March 30, 2022), the very rapid flow of the Blue Nile enables this deposit, contrary to the White Nile which is slower and carrying different types of rocks and sands.

The red brick producers are then concentrated along this Blue Nile, from al-Damazin to Khartoum, and then on the main course of the river until it reaches Egypt. The kilns (*kama'in* in colloquial Sudanese Arabic - كمائن) are located on the banks of the Nile, so the silt can be collected directly (Fig. 1). This dependence on the Nile floods implies a seasonal functioning, the kilns being active only from September to May, when the banks are not flooded.

More precisely, the red brick producers identify three main types of silt : the *guerara* one, the *zafout* one, which is more sandy, and the *balabati* one[1]. These three types have to be mixed with proper proportions in order to get a good brick. A producer in Omdurman explains : « If there is too much *zafout*, the brick will be weak. If there is too much *balabati*, the brick will be dry and will break. If there is too much *guerara*, the brick will crack. » (interview, April 16, 2022). These silt types are unequally distributed in Khartoum. According to a producer in al-Gereif Sharg (interview, March 6, 2020), the silt deposited in his area is particularly good, which explains the massive red brick production in this area.

Thus, the quality of the red brick depends on the general quality of the silt, but also on the experience and the skills of the kiln owner who will recognize the different types of silt, its characteristics and use a proper mix for his production. The whole silt is then mixed by workers with water and an organic material, generally cow dung, in order to enhance the adherence of the mixture. The production process in Sudan is handmade, the bricks being manually moulded and fired in ephemeral kilns (Fig. 2) which are dismantled after each firing. The final product is a roughly 19 cm long and plain brick. The quality of the burnt bricks is also different inside the kiln and bricks are classified in three categories, according to their level of firing (Fig. 3).

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[1] According to Omer Ali Mohamed Ali (2008), the *balabati* is a « very plastic clay with a fraction of clay varies between 20% - 25% » (p. 26), the *zafout* is « containing 10% clay, 15% sand and the rest is silt » (p. 27) and the *guerara* shows very low plasticity as it is a « sandy silt with the sand portion varying from 20% to 40% and the rest is silt » (p. 27).

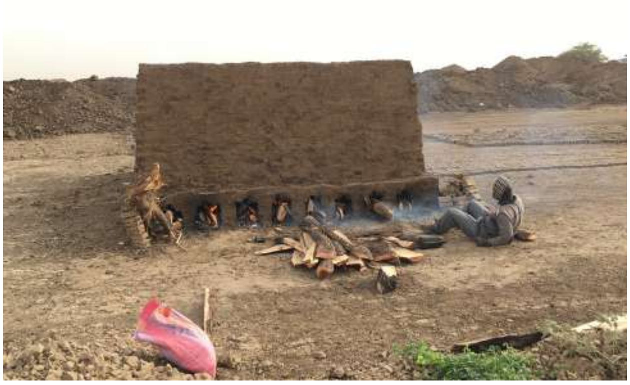

Figure 2: A burning kiln in al-Gereif Sharg (Khartoum).
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The Egyptian red brick producers also rely on a clay material (*ṭefla*), but it is extracted from mountainous quarries. These quarries are located on the margins of the Nile valley because the river bed has moved across the geological eras, which has created alluvial plains at its fringes (SHATA, 1988). The shale clay areas are mainly concentrated between Cairo and Beni Suef, but some can be also found on the Western part of the Delta, close to Wadi Natrun lake, or on its Southern-Eastern part, close to Bilbeis (بلبيس). The main production areas are in Arab Abu Said and al-Saf, south of Cairo (Fig. 4).

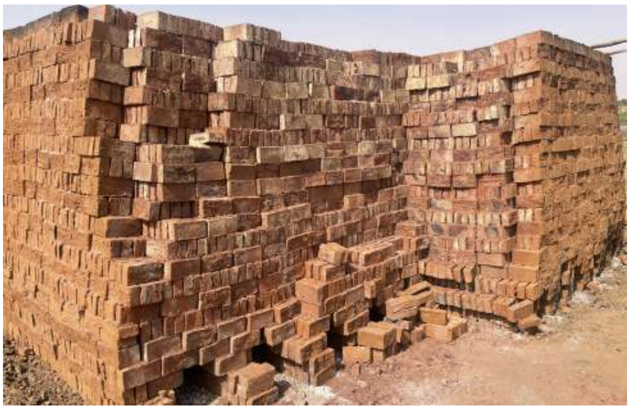

Figure 3: The different red brick qualities inside a kiln in Hillat Koko (Khartoum).
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As for the Nile silt in Khartoum, there are different types of shale clay and the quality can vary from quarry to quarry. Red bricks are made from a mixture of a « yellow clay » (*ṭefla safra*), a « brown » one (*ṭefla samra*), which is more viscous, and sand (interview with a producer in al-Rihawi, March 9, 2022). If sand can be extracted in many different parts of Egypt, shale clay can only be found in the aforementioned quarries. The proportions between these three main components depend on the experience of the producer, its ability to identify the shale clay characteristics and to supply his factory with high quality clay.

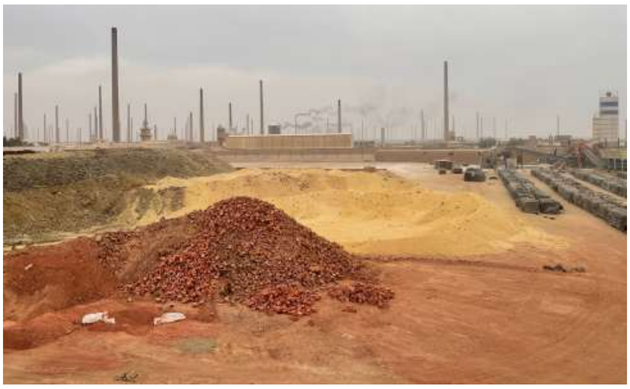

Figure 4: Arab Abu Said, the main red brick production area in Egypt.
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According to interviews with some producers in 2022, the quarries of Dahchour and Girza are providing the best quality of clay in Egypt. But the general shift to these quarries, on the Western banks of the Nile, approximately 50 km south to Cairo, is recent. Based on what a producer in al-Qalyubya governorate told me (May 10, 2022), this shift depended on two main factors : the poor quality of other quarries, like the ones in 10th Ramadan and Bilbeis, and the running out of Arab Abu Said quarries which provided the best quality.

The distribution of red brick factories is highly dependent on the localization of these quarries, as the producers try to save money on transportation costs. A fully functioning factory may need the supply of three trucks a day, which highlights the importance of the localization of the factory and of the quarry in a context of rising fuel prices in Egypt. The process is much more industrialized and mechanized than in Sudan, which results in an alveolar red brick (Fig. 5).

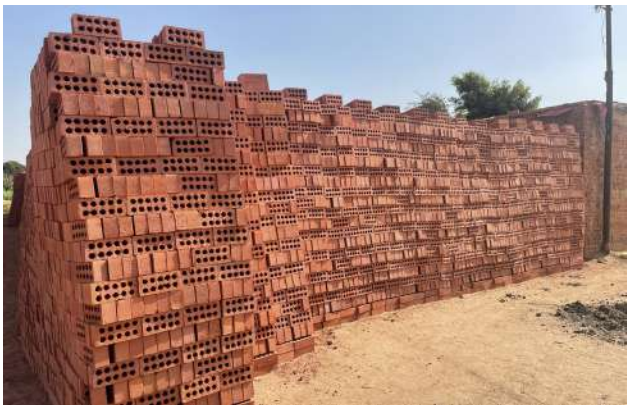

Figure 5: The classic alveolar bricks in al-Qaliubya governorate (Egypt)
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These two opening descriptions of the red brick supply chains in Egypt and Sudan and of the earthen materials which are used are a necessary prerequisite for a better understanding of the transformations of this building material. Then, one has to keep in mind that the Sudanese producers rely on a renewable clay, which they collect directly on the banks of the river, while the Egyptian ones depend on the extraction of another type of clay, which can be found in some quarries only and which seems to become scarce. These two very different contexts regarding the access to the main raw material are determinant for the functioning of the whole supply chain, as I will show it in the next part about the consequences of the shift from Nile silt to shale clay in Egypt.

2. CHANGING THE CLAY, INDUSTRIALIZING THE PRODUCTION ?

Until the 1980s, red brick production in Egypt was mainly manual and the producers were using the Nile silt, as it is still the case nowadays in Sudan. What caused this discrepancy ? Why is the Nile silt still used in Khartoum whereas it has been replaced by shale clay in Egypt, despite the proximity between these two countries ?

The main reason is infrastructural. The completion of the High Aswan Dam in the late 1960s by the Egyptian president, Gamal Abdel Nasser, completely disrupted the red brick sector. This water control and electricity production infrastructure led to the interruption of the seasonal floods in Egypt which affected directly the producers (McKenzie, 1985). They had to turn from the renewable Nile silt to the agricultural soils in the valley, which have approximately the same properties. Nevertheless, the government quickly forbade this process of digging agricultural soils, called *tagrif*, through a series of legal texts, from the 1966 Agricultural Law to decrees promulgated by Hosni Mubarak in 1985 (*Ibid.*). This legal framework forbids completely the use of Nile silt or agricultural soil for another purpose than agriculture. Progressively, the red brick producers were then incited to use another raw material, namely the shale clay.

This shift led to a series of material transformations in the supply chain. Firstly, regarding the localization. Although most of the production units were located on the banks of the Nile and in the Delta, some producers started to abandon these factories to settle in areas close to shale clay quarries. Industrial concentrations were informally and progressively established in these areas, such as in Arab Abu Said and in al-Saf which gather approximately 500 factories among the 1200 scattered in the whole country.

The other major consequence of this shift in the earthen material used is the industrialization of the supply chain. Shale clay is indeed more rocky and less viscous and malleable than the Nile silt (Figs. 6 and 7). These properties make it very difficult to be mixed and moulded manually, even if the Egyptian producers started to use it in their lowly industrialized production units in the 1990s. But they had to invest in machines, especially for the compression of the brick, as this producer says : « Before the machines, the *ṭefla* brick used to break easily. This *ṭefla* is not adapted to a manual production and the machines improved the quality of the product and the efficiency of the factory » (May 10, 2022).

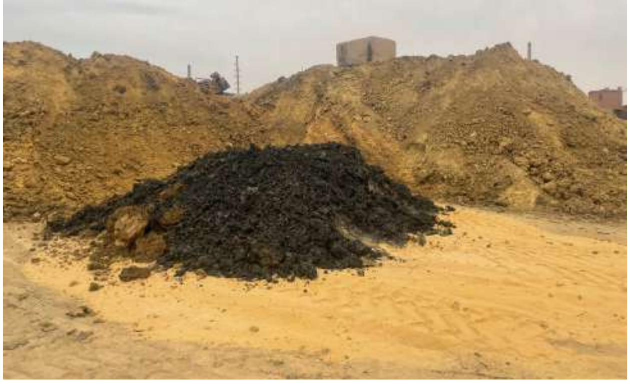

Figure 6: The « brown » and the « yellow » shale clays in Arab Abu Said (Egypt)

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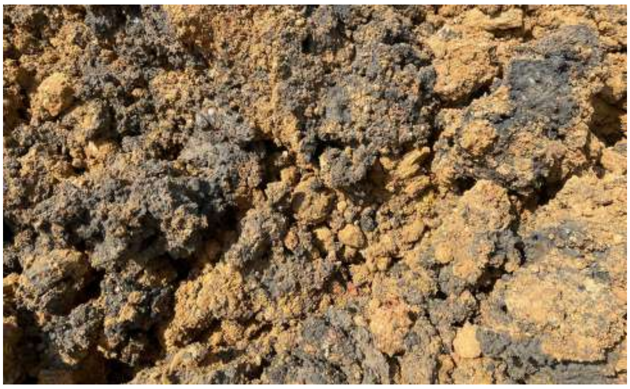

Figure 7: The two types of shale clays mixed in a factory in al-Rihawi (Egypt)

© C. Pérez-Houis, March 2022

Finally, this use of *ṭefla* led to change the structure of the brick, from plain to alveolar. As McKenzie (1985) explains, this new clay material is denser than the Nile silt. Its use makes the brick heavier than the previous one and it became almost mandatory to perforate it in order to lighten it. This transformation was also only possible through an industrialization of the production process, as machines are needed to get an alveolar brick (Fig. 8). It also led to a needed adaptation of the Egyptian producers' *savoir-faire*.

All of these transformations, resulting from a replacement of the initial earthen material, happened in the 1990s in Egypt but didn't concern the Sudanese supply chain. The latter is not industrialized and mechanized, the bricks produced are plain and less standardized and, of course, Nile silt is still used. One could argue that Sudanese producers, in accordance with the

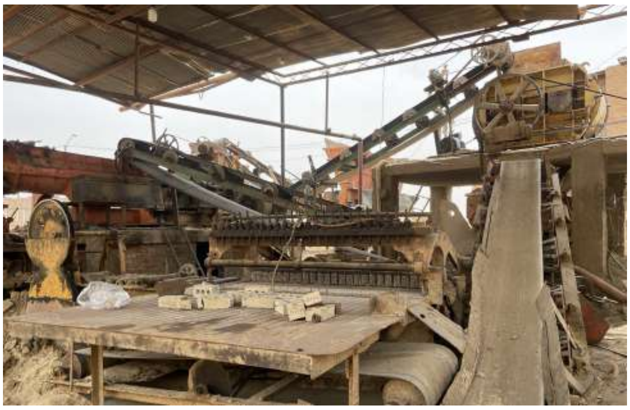

Figure 8: An interrupted production line in Fayoum oasis (Egypt).

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general economic situation and the low level of industrialization in the country, are just late or less advanced than the Egyptians.

On the contrary, I would like to show that the permanency of a manual production in Sudan is linked with both structural and circumstantial factors. The absence of a High Dam and the continuing floods are a first fact that explains this situation. The red brick producers can still rely on the seasonally deposited Nile silt, a renewable and cheap resource. Another argument against the economically centered and aforementioned analysis is the actual attempt, in the 1980s, of Sudanese public actors to move the producers from the river banks to peripheral areas. Some areas were identified, such as Aid Babiker and Sheikh al-Amin, on the Eastern fringes of Khartoum, as proper areas to extract clay from alluvial plains and establish red brick factories. However, this plan wasn't implemented. The resistance of producers to be relocated far away from the urban areas and the high costs of the operation made it fail, according to an engineer in the Geological Research Authority in Khartoum : « It failed because of the transport costs and the lack of water resources. They had to dig a well, which is very costly » (interview, March 30, 2022). The political context, namely the military coup in 1989 by Omar al-Bashir and the apparent lack of interest of the new rulers for these red brick producers, is also to be taken into account in order to explain the current situation of the sector.

The analysis of the progressive shift from Nile silt to shale clay in Egypt and of the discrepancy with the Sudanese case show the entanglement of technical, engineering, geopolitical and economic issues. It seems all the more important to understand these progressive material changes of the supply chains as the conditions of access to the raw materials are more recently evolving.

3. A GROWING DISTANCE BETWEEN CLAY RESOURCES AND RED BRICK PRODUCERS

Even if contexts are different between both countries, access to the clay resources, either be it the shale clay or the Nile silt, seems to be more and more difficult for both Sudanese and Egyptian red brick producers.

In Sudan, the producers access to the Nile silt directly on the land they work on. This resource seems to be abundant enough to supply for the surrounding kilns for a whole production season. However, these kilns are highly criticized by a series of institutional actors, such as local governments, international institutions and academics (Abu Shura, 2000 ; Alam and Starr, 2009 ; Abdallah, 2013). These actors highlight the air and water pollution provoked by the production and burning of these bricks, but also the fact that the digging of the silt is creating holes in the banks of the river and that producers overexploit this naturally renewable resource (Fig. 9). On this basis, these criticizing actors argue that red brick producers need to be removed from the banks of the Nile and relocated to the margins of the Sudanese capital. A series of decrees, relying on environmental and sanitary arguments, forbid the production of this building material on the banks of the Nile inside Khartoum area (Pérez-Houis, 2022). Producers would be moved away from the source of the earthen material they use for their activity, which, as mentioned before, didn't really happen for economic and political reasons.

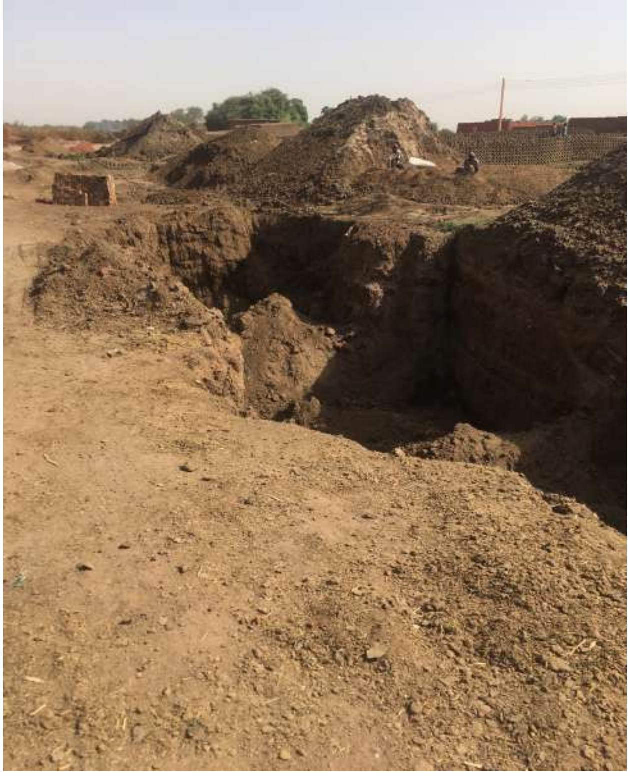

Figure 9: Holes dug in the Nile banks by red brick producers in Soba (Khartoum).

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Egyptian producers were concerned by the same issues in the 1980s and the 1990s, with the mandatory replacement of the Nile silt by the shale clay. Until recently, the shale clay quarries were controlled by local operators to whom red brick producers bought directly the material, before delivering it to the factory by trucks. The factories located close to these shale clay quarries obtain a relative advantage compared to the producers who are still on the banks of the Nile or in the Delta region. For example, some red brick factories used to be located in al-Warraq area, on the banks of the river inside Cairo. One of the former producers, according to an interview I led with him, turned from Nile silt to shale clay in the late 1980s. But, quickly, in 1992, he had to interrupt his activity because of the rising price of the shale clay, the cost of transport and his lack of competitiveness compared to all the factories located in Arab Abu Said, close to the quarries (interview, May 31, 2022). This example shows the high dependance of red brick producers to the price and localization of the earthen resources.

Besides, the conditions of access were recently tightened as the military took control of the quarries. The army is a very powerful economic actor in Egypt, being present in almost all sectors (Abul-Magd, 2018 ; Amar, 2018 ; Sayigh, 2019). However, they were not directly involved in the red brick production but rather in the cement one, until a recent modification of the Law 198/2014 on the mineral resources. The Law 145, promulgated in 2019, made mandatory the approval of the Ministry of Defense to obtain an exploitation permit in the quarries. Practically, the military actors recovered administrative and judiciary control on most of the shale clay quarries, which led to a higher formalized system of exploitation and to a quick price increase. According to a contractor in Fayoum oasis, who is buying red bricks on a daily basis for his construction sites, this reorganization of the shale clay quarries was indeed directly visible in the price hike of red bricks (interview, May 14, 2022). A sales manager in a red brick company confirmed this fact : « The increase in the prices of the shale clay is linked to the taking of control of the quarries by the army. The exploitation was informal until then, but now it is controlled, the quantities are precisely counted » (interview, June 19, 2022). The military control of the quarries is not only an economic issue, but also political as the functioning of these institutions is often very opaque.

Finally, these different conditions of access is reflected in my own opportunities of access to these clay sources. In Sudan, it has been easier of course, as the Nile silt is directly located next to the kilns. But in Egypt, even if I could observe the different types of shale clays used in the factories, I have never been able to visit a quarry. The producers I met never proposed it to me, even though I asked many questions on this clay and its characteristics. In a context of high tensions about qualitative research and security issues in Egypt, I didn't insist too much and these quarries stayed inaccessible for the whole length of my fieldwork. This reflects the potential suspicion raised by my questions and my presence, the high number of controls on the roads and maybe also the recent military takeover on these quarries.

CONCLUSION

This paper dealt with the clay resources in Egypt and Sudan through their use in the red brick production. This focus on the earthen materials enables the articulation of technical and geological issues with economic and geopolitical ones. The economic and geographic conditions of access to these clay resources should be analyzed deeper in further research. The different criteria identified by the producers to choose one quarry over another (quality of the clay, localization, distance to the factory, price of the gasoline…) are still to be more clarified. However, as shown in the last part, the Egyptian quarries are now under the supervision of the Ministry of Defense, which impedes a qualitative research about it, and the current war in Sudan makes it all the more difficult to investigate the red brick production units.

Besides, I argued in this paper that the discrepancies between both supply chains, in terms of level of industrialization and mechanization, cannot be understood as a development or underdevelopment matter. There is not a chronological linearity of development, that would go from unburnt bricks to burnt bricks handmade with Nile silt to industrialized ones made of shale clay. The transformations of the red brick production depend on a high variety of factors, including the properties of the clay, the localization of the factories and the accessibility of these earthen resources.

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CONSOLIDATION OF ADOBE BRICKS FROM THE CHURCH AT MISEEDA. BIOCALCIFICATION OF ADOBE, BASED ON A BIO-BASED LIQUID IMPREGNATION SYSTEM

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SUMMARY

Climate change in recent decades has resulted in more rainfall in Lower Nubia. Not only in the wet season (Summer) but also in Winter and Spring there is increasing rainfall. In the region of the Third Cataract, near the village of Miseeda, a church building dating back in its present form to the 9th or 10th century that is still standing up to a considerable height has suffered visibly from erosion during the past 30 years. An archaeological mission of the University of Warsaw has started an excavation and conservation project in 2020 in the framework of which walls are and will be reinforced and reconstructed with new mud-bricks. In addition to this experiments have been carried out at the Technical University Delft that are meant to make mud-bricks more water resistant through biocalcification. The results show that after impregnation water-resistance has increased. Given the unstable situation in Sudan at the moment a continuation of experiments in the field is not possible, but will be carried out when better times will come.

INTRODUCTION

In archaeological fieldwork, after the main task concentrated on excavations and research, protection of the monuments is the next important issue. This task in the Nile Valley very often concerns the problem of protection of the mud-brick structures. Within the project started in 2020 by a mission of the University of Warsaw in the vicinity of the village of Miseeda such a task plays a very important role, focused on the church that is a central part of the research concept. The task of protection and conservation of the church architecture and its paintings has also a research aspect. We decided to test a new method of reinforcement/impregnation mud-bricks by using the biocalcification method[1].

1. CLIMATE CHANGE AS A RISK FACTOR OF THE MONUMENTS IN NUBIA

The most important cause of the increasing damage to the church is the change in climate of the past decades and as one of the implications of this the increase of rainfall. The northern part of Sudan (Nubia) has a rainy season that coincides with Summer. The farther north from Khartoum one would

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[1] Authors would like to thank prof. dr hab. eng. Romuald Tarczewski for the idea to test the biocalcification method for the Miseeda mud-brick impregnation.

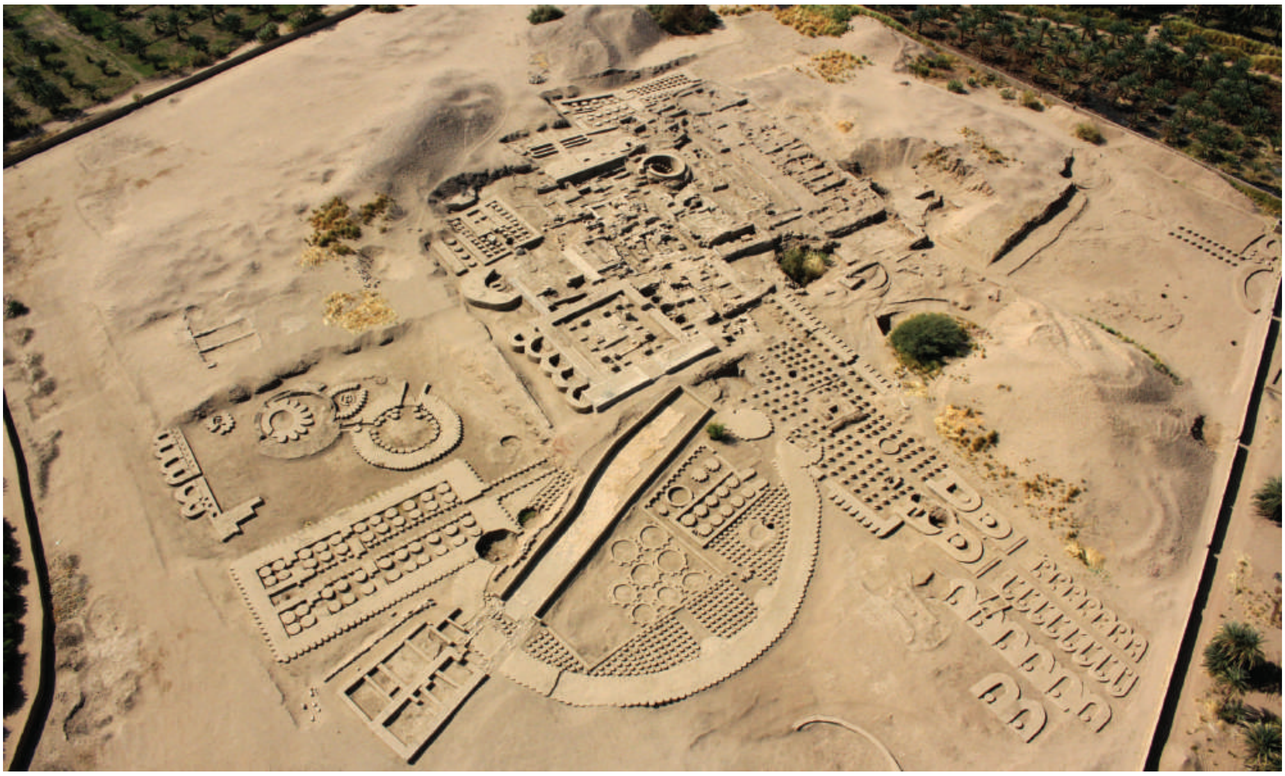

Figure 1: The site of Doukki Gel.

© (http://kerma-doukkigel.ch/en/)

come, the less rain would fall during this wet season. Nowadays rain has been even witnessed during Winter in the region of the Third Cataract.

Increased and more frequent precipitation is one of the most urgent risk factors of the architectural monuments in Nubia. Adobe is the traditional building material in this region since millennia and vernacular architecture and archaeological monuments face increasing erosion.[2] The monuments of Kerma and Doukki Gel (ca. 2700-1200 BCE), located ca. 40 km south of the Third Cataract and excavated by Swiss and French archaeologists, are representative of the monumental shapes and dimensions of Nubian adobe architecture (Fig. 1). Not only the church of Miseeda, but countless other monuments are in need of a solution to preserve them in the short and long term.

2. THE CHURCH OF MISEEDA

The Third Cataract landscape in Sudanese Nubia (Fig. 2) is dominated by rocks and boulders of volcanic origin that have formed a natural border between north and south since millennia until the present day. In the early Christian period the border between the kingdoms of Makuria (south) and Nobadia (north) was here and until now the two different dialects of the Nubian language are spoken north and south of the Third Cataract, as a remnant of this characteristic of the region as a border area. Possibly connected with this is the fact that the region is rich in petroglyphs and graffiti covering a period of thousands of years. Travelers may have wanted to leave a memento of their crossing of the border.

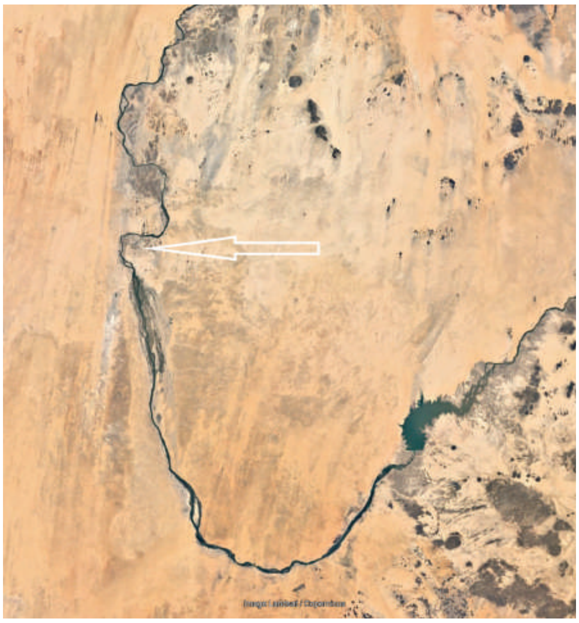

Figure 2: The Third Cataract region and location of Miseeda village.

© Google Earth

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[2] For the tradition of using mud-brick in Nubian architecture in medieval period and nowadays, according to the climate conditions, see Anderson 1996: 199-206.

Among the many minor petroglyphs and graffiti a number stand out by their size and artistic quality. One of these, in a Wadi Farja that ends at the village of Miseeda, represents a man in Kushite elite costume, holding two spears or staffs with triangular flags attached, while leading two rams or goats. Both the dating (somewhere between 700 BCE and 300 CE) and the iconographic interpretation of this petroglyph are still uncertain, but in the early Christian period it must have been re-interpreted as a figure of Christ. This is evident from the fact that a church was built with the rock-drawing as its centrepiece. The figure occupies the eastern wall of the sanctuary, a place that usually is taken by a figure of Christ (Fig. 3). The remains of the church as they stand today show characteristics of the 9th/10th centuries, but older walls that were incorporated in this structure reveal that its origin goes back to an earlier period.

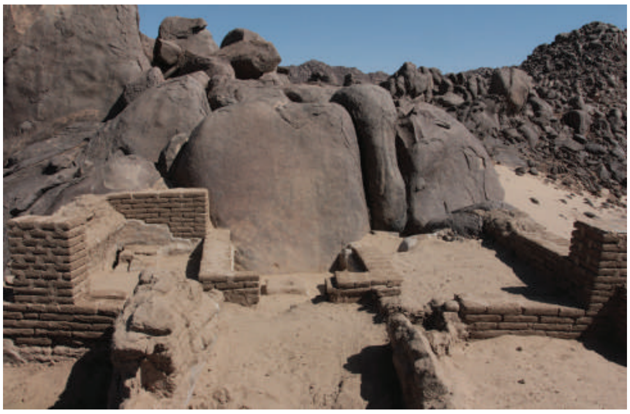

Figure 3: The boulder with the Kushite petroglyph.
© C. Calaforra

The location and the importance of this archaeological monument were known for decades[3] , but it was not until recently that investigation and conservation work were started. In the meantime the dilapidation of the church had taken serious proportions. Arches and walls that were still seen standing in the 1990s have collapsed (Figs. 4-7).

3. IMPREGNATION AS A PREVENTIVE FORM OF CONSERVATION

Impregnation as a preventive form for conservation of mud brick is not new. In the recent past experiments have been carried out with impregnation with sodium silicate[4] and with ethyl silicate[5], which seem to have been successful. These tests were carried out under laboratory conditions and to our knowledge no experiments with these methods have (yet) been carried out by archaeologists in the field. In these laboratory experiments a hydrophobic layer of several mm or cm thick was created by absorption of sodium silicate or ethyl silicate. The difference with the experiments with mudbrick from Miseeda is that the absorbed substance triggered a bacteriological process that had the formation of a hydrophobic layer as a result. After tests in the laboratory tests of the method in the field (Sudan) were planned. These, however, had to be postponed indefinitely due to the political situation in Sudan at present.

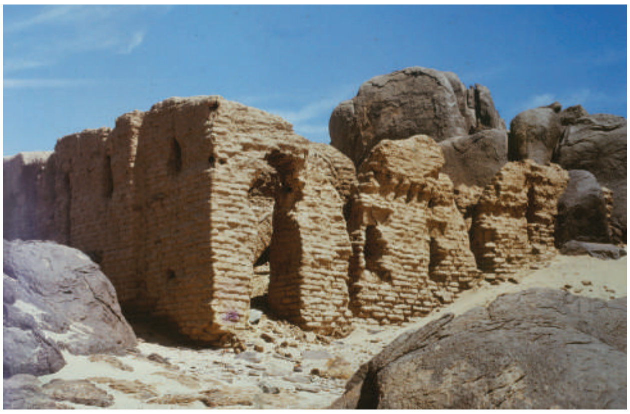

Figure 4: The church seen from SW in 1993.
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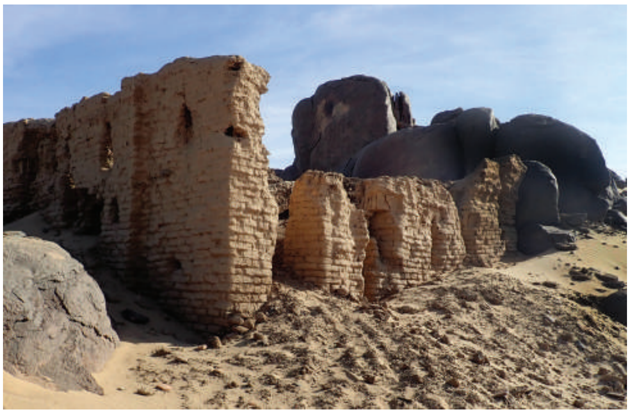

Figure 5: The church seen from SW in 2018.
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4. TESTS CARRIED OUT ON ADOBE BLOCKS FROM MISEEDA

4.1. METHODOLOGY

The use of bacteria for the reinforcement and repair of construction materials has been a subject of experiments and study in the past decade. It has been applied to a wide variety of modern construction materials, from concrete and cement mortars, ceramic clay bricks and earthen bricks to limestone and gypsum plasters. It is a sustainable technique with great improvements on the properties of these materials.[6] Apart from being applied in sustainable and affordable building techniques, this biocalcification can be an effective method in the conservation of earthen architecture as part of historical and archaeological heritage. Till now the method has been tested using bacterias in laboratory conditions.

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[3] Osman, Edwards 2011, 65, 66, 167-170

[4] Ren, Kagi 1995.

[5] Garcia-Vera *et al.* 2020.

[6] For references to application in these materials see Parracha *et al.* 2019.

In order to explore the possibilities of biocalcification for the church of Miseeda, four bricks collected in the debris of the church were imported to Poland and then to the Netherlands to perform the tests. Four samples taken from the bricks were analysed to compare the original chemical composition and structure before and after the treatment.
For this reason the experimental impregnation of the bricks by using biocalcification method has been conducted using the ready made Basilisk ER77 as a preliminary research for further investigation at the archaeological sites. In this research project the ER7 system was for the first time applied to adobe in order to investigate whether this bio-based product could also result in stabilization of loose and aged adobe.

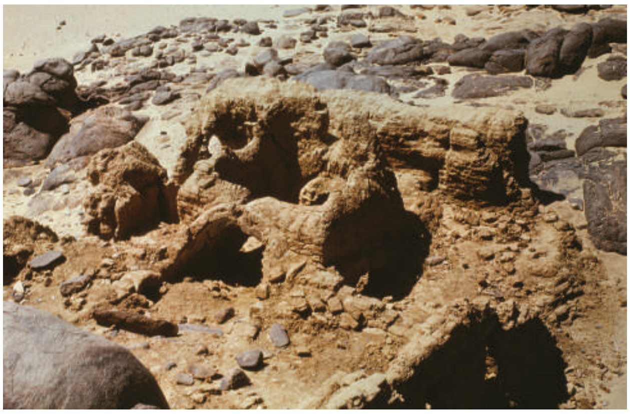

Figure 6: The church seen from NE in 1993.
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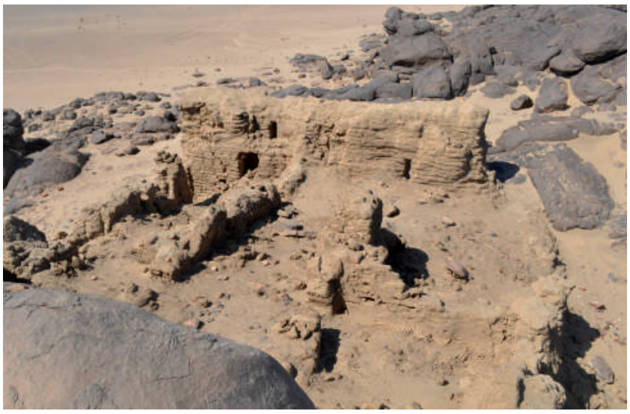

Figure 7: The church seen from NE in 2018.
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The liquid impregnation system was originally intended to densify porous and cracked concrete structures. The impregnation system consists of two liquid solutions that must be sequentially sprayed on porous surfaces. The first solution contains bacterial spores (dormant bacteria) of alkali-resistant soil-derived bacteria related to the species Bacillus cohnii, sodium silicate, yeast extract and gluconate. Latter two compounds are nutrients that stimulate germination of spores and growth of bacteria while sodium silicate provides the required high alkalinity. The second solution contains highly concentrated but soluble calcium salt. Once sequentially applied the two liquids form a soft gel due to the polymerization reaction of silicate ions from the first solution and calcium ions from the second solution. This hydrogel activates the bacteria which subsequently metabolically convert gluconate to insoluble calcium carbonate under the prevailing alkaline conditions. The produced calcium carbonate densifies pores and cracks thus stabilizing and waterproofing the material.

The untreated and impregnated samples (after the rain shower test - see below) for stratigraphic studies were embedded in epoxy resin, Epofix (Struers), and polished on a mechanical grinder-polisher Labo-Pol 2 (Struers) using silicon carbide waterproof abrasive foils at successive grits of 120, 180, 320, 500, 1000, 2000, 4000. Elemental composition of the samples was determined using Zeiss Sigma Vp scanning electron microscope (SEM) combined with X-ray energy dispersive spectrometer (EDS). EDS measurements were used to calculate cementation index.[8]

4.2 THE EXPERIMENT

Adobe blocks from Miseeda were treated in the laboratory at TU Delft. Reference blocks were not treated (see Fig. 8) and other blocks were either treated once (Fig. 9), twice (Fig. 10) or three times (Fig. 11) with three-weeks interval periods.
The mud blocks were sprayed two times on all sides with ER7 solution A with 15 min time in between followed by spraying two times on all sides with ER7 solution B also with a 15 min time interval (also between last solution A and first solution B treatment).

Mud blocks (including reference samples which were not treated) were subsequently stored in closed plastic buckets to avoid rapid evaporation of moisture and to allow bacterial activity. Buckets were stored for 3 weeks at room temperature. Results showed that a layer of soft white fungi developed on the surface of blocks after one treatment but that this layer diminished after second and third treatment with ER7.
The treatment was repeated on part of the samples (set 2) after 3 weeks.
The treatment was repeated on part of the samples (set 3) after again 3 weeks.
9 weeks after the start of the experiment thus 4 sets of specimens remained and were subjected to the water erosion ‘rain’ test (set 1 reference = specimens not treated at all; set 2 = specimens treated with ER7 once and incubated for 9 weeks; set 3 = specimens treated with ER7 twice and incubated 3 + 6 weeks; set 4 = specimens treated with ER7 three times and incubated 3 + 3 + 3 weeks).

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7. https://basiliskconcrete.com/en/products/product-liquid-concrete-repair-system-er7/

8. Figueiredo *et al*., C., Lawrence, M., Ball, R. 2016.

The ‘rain’ test was done by subjecting all specimens after 9 weeks incubation to a shower treatment (as shown by the video). For this specimens were placed on a mesh wire plate and subjected to a shower treatment for 5 minutes. The 5 minutes were chosen based on a preliminary test with reference specimen to make sure that at the (fixed) water intensity applied some erosion occurred but not leading to full disintegration of the specimen. The distance between shower head and specimen was 50 cm.

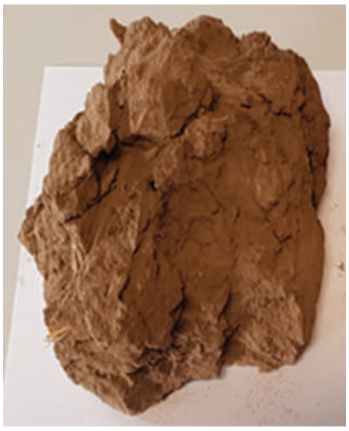

Figure 8: Reference sample, untreated.

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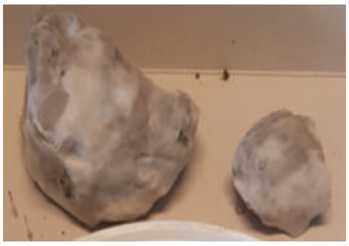

Figure 9: 1x treated samples.

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In comparison to the untreated reference blocks, all treated blocks showed high water repelling performance and significantly increased water erosion capacity and thus improved consistency.

An indication for an increased water resistance is the reduced loss of weight. This weight difference of samples between before treatment and after treatment and the rain test (including drying) can be summarised as follows:

Reference samples (n=10)(untreated)	-12% (= weight loss)
Samples 1 (n=5)(1x treated)	+1% (= weight gain)
Samples 2 (n=3)(2x treated)	0%
Samples 3 (n=4)(3x treated)	0%

Weight loss can be explained by erosion, while weight gain seems difficult to explain, unless absorption of water is the reason.

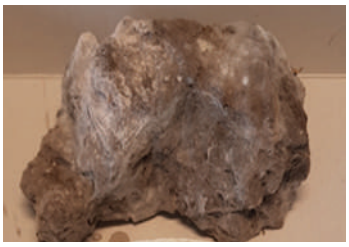

Figure 10: 2x treated samples.

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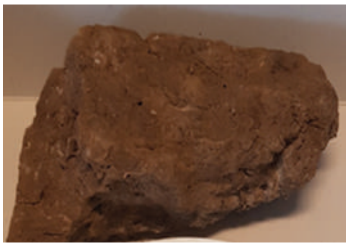

Figure 11: 3x treated samples.

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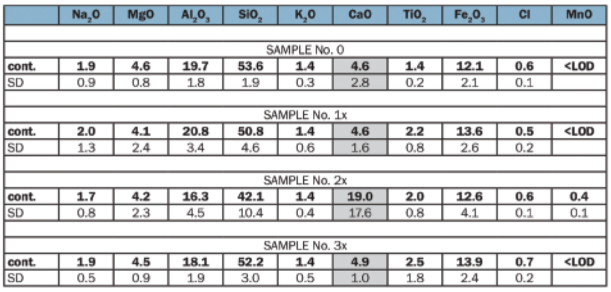
4.3 CHARACTERISTICS OF THE MUD-BRICKS

All analysed adobe brick samples (the untreated one and impregnated ones after the exposure to the rain shower test), are characterised by a similar chemical composition. Sample 2x treated with Basilisk Liquid Repair System ER7 is distinguished by a higher calcium oxide (CaO) content in some of the subsurface areas of the investigated material, which also reflects in a lower value of the cementation index calculated according to the formula:

$C.I. = (1.1\ Al_2O_3 + 2.8\ SiO_2 + 0.7\ Fe_2O_3) / (CaO + 1.4\ MgO)$[9]

However, high standard deviation value indicates inhomogeneous content of calcium. In other samples (sample 0, sample 1x and sample 3x treated) cementation.



	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	Fe_2O_3	Cl	MnO
SAMPLE No. 0										
cont.	**1.9**	**4.6**	**19.7**	**53.6**	**1.4**	**4.6**	**1.4**	**12.1**	**0.6**	**<LOD**
SD	0.9	0.8	1.8	1.9	0.3	2.8	0.2	2.1	0.1	
SAMPLE No. 1x										
cont.	**2.0**	**4.1**	**20.8**	**50.8**	**1.4**	**4.6**	**2.2**	**13.6**	**0.5**	**<LOD**
SD	1.3	2.4	3.4	4.6	0.6	1.6	0.8	2.6	0.2	
SAMPLE No. 2x										
cont.	**1.7**	**4.2**	**16.3**	**42.1**	**1.4**	**19.0**	**2.0**	**12.6**	**0.6**	**0.4**
SD	0.8	2.3	4.5	10.4	0.4	17.6	0.8	4.1	0.1	0.1
SAMPLE No. 3x										
cont.	**1.9**	**4.5**	**18.1**	**52.2**	**1.4**	**4.9**	**2.5**	**13.9**	**0.7**	**<LOD**
SD	0.5	0.9	1.9	3.0	0.5	1.0	1.8	2.4	0.2	

Figure 12: Average chemical composition [wt.%] of the analysed samples [calculated on 9 measurements].

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THE RESULTS AND CONCLUSIONS

Adobe blocks treated with the bio-based impregnation system ER7 showed various levels of resistance against water erosion due to increased water repellency performance and improved consistency in comparison to non-treated reference blocks. This improved performance is thought to be due to both formation of a water repellent bio-based layer on the surface of adobe blocks as well as to the formation of calcium carbonate due to bacterial activity resulting in consolidation of the loose adobe material. However, the chemical tests didn't show any substantial differences in structures nor in the level of CaO in the examined samples (although this can be caused by the fact that the impregnated samples were examined after the shower rain test and the high level in the sample treated 2 times shows the change). Nevertheless, the results show that treatment of adobe material with ER7 appears a promising bio-based technique for consolidation and preservation of adobe structures and further tests should be continued in the field as soon as circumstances allow. Two important questions are still unanswered:

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[9] Figueiredo *et al*. Chemical and physical characterisation of three nhl 2 binders and the relationship with the mortar properties 2016, 3.

For a successful course of the bacteriological process a high humidity in the mudbrick is required. Under laboratory conditions this can easily be achieved by wrapping the mudbrick in plastic foil. In the field this high humidity should be achieved either by working in the wet season (Summer) and/or covering the treated wall surfaces with plastic after impregnation. The practicalities of this are to be investigated.

The cost-effectiveness of working with ER7 should be compared with the results of working with 'conventional' methods, i.e. impregnation with sodium silicate and ethyl silicate.

ACKNOWLEDGEMENTS

The analyses were conducted within the project "The Good Shepherd of Miseeda. An image in the context of the changing cultural landscape of the Third Cataract of the Nile." financed by the National Center of Science (grant no. 2019/35/B/HS3/02440)

The experiment at the Technical University of Delft was conducted as a part of the PhD research of Yask Kulshreshta (Faculty of Civil Engineering and Geosciences) under supervision of Prof. dr. Henk Jonkers, which has as a main objective the development of building methods for affordable water resistant housing of adobe in India.

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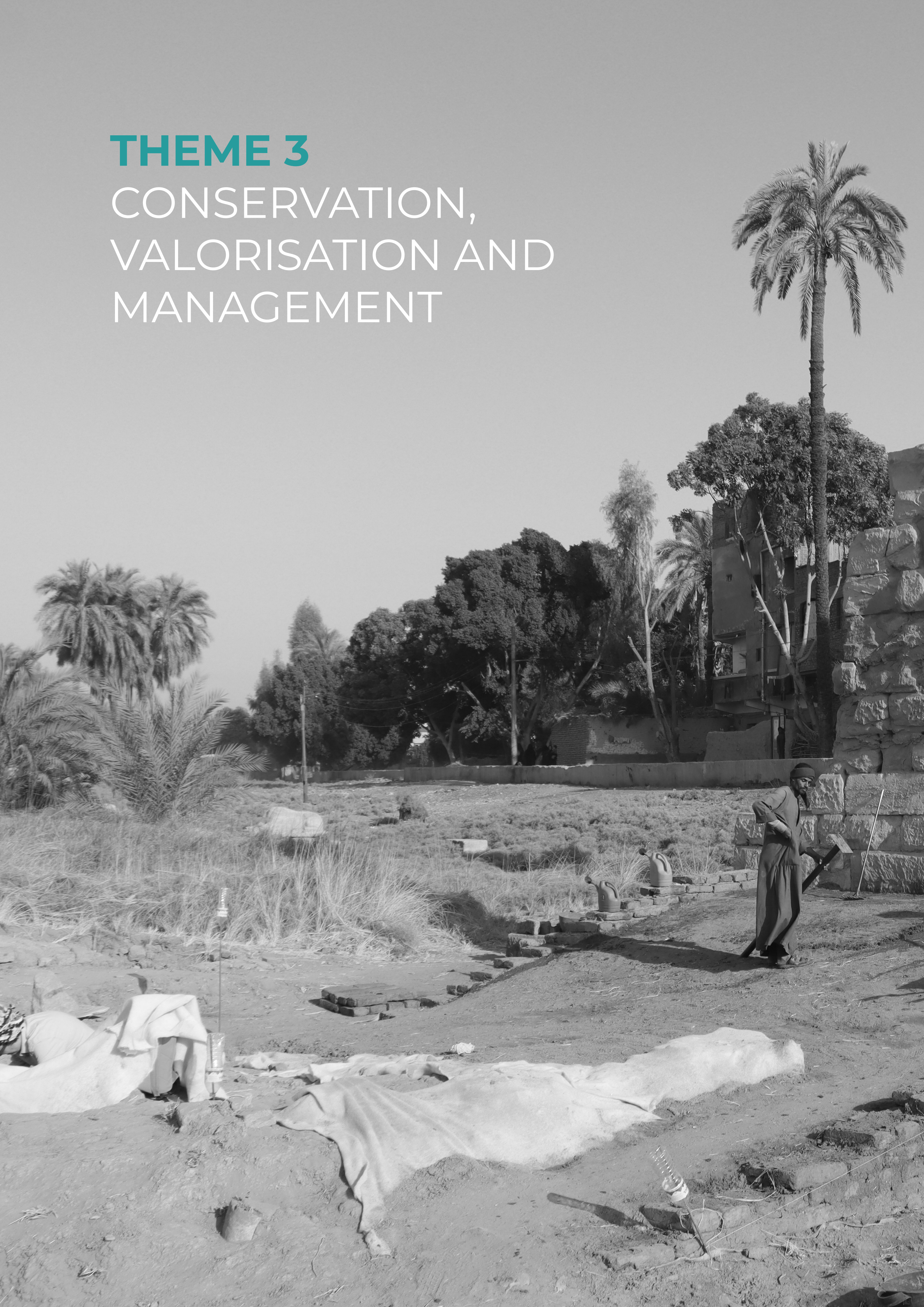
THEME 3

CONSERVATION, VALORISATION AND MANAGEMENT



Medamud, Egypt © T. Joffroy

EXCAVATION TO CONSERVATION, THE MUD BRICK PYRAMID OF TETISHERI

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SUMMARY

The title is a bit misleading, as it may imply that there is a distinct break, a significant difference, between the excavation of a site and its architecture and its conservation. In this case, this implication could not be further from the truth when applied to ancient archeological sites. From the actual excavations to the completion of conservation interventions, there is an ongoing collaboration between the archeologists and the conservators. A site is excavated, features identified, site, archeological and architectural values are studied, all a part of the discovery process. Planning for interventions can then begin but questions will continue to arise, often requiring additional focused excavations to further understand the complexities of the site that may be affected by interventions. This is particularly true when the site and its architecture is unusual or unique. The mud brick pyramid of Tetisheri at Abydos is a unique structure and, along with the nearby pyramid mound of Ahmose are the last royal pyramids in Egypt. The symbiotic relationship between the disciplines of archeology and conservation was a vital component of the project to conserve and present the important values such as to answer critical questions of how it was constructed and to a lesser extent, how it eventually deteriorated, both of which are presented in the conservation program.

INTRODUCTION

The mud brick pyramid of Tetisheri in Abydos was constructed by King Ahmose I in the beginning of the eighteenth dynasty, ca. 1550 BCE, to honor his grandmother Tetisheri. While Ahmose constructed his much larger pyramid of a solid construction system, Tetisheri's pyramid utilized a cellular system of mud brick walls. The site was excavated in 1904, again in 2004 and in 2010. It was backfilled after the 2010 excavation program and the first task of the current program was to re-excavate the site, which occurred in October 2022. This latest excavation proved more time consuming and required more efforts than originally thought as the level of detail in reports from the earlier excavations was insufficient to thoroughly understand the structure to the level necessary for the program proposed to the Ministry of Tourism and Antiquities by the project team. The overall goals of the project were to stabilize and protect the structure into the future and to restore enough of the structure to make it clear exactly how the pyramid was originally constructed and how it could best be presented and interpreted. Prominent features to clarify by partial restoration were (1) the actual slope of the exterior walls, (2) the basic pyramid geometry, (3) the structural system and how it performed, and (4) the structural deformation and the failure and collapse of the pyramid. Basically, our goal was to protect and restore where necessary, while retaining the basic characteristics of the pyramid remains. The basic plan was developed after the October 2022 field work and was presented to and discussed in February 2023 with Dr. Mohamad Naguib, General Director of Abydos Antiquities, Ministry of Tourism and Antiquities.

Additional excavations and initial stabilization began in February 2023. The site had been laser scanned and documented by field drawings and high rez photography prior to the additional excavations. We realized quickly that sections of the pyramid had not been excavated as we had assumed. Also, evidence that had been referred to in earlier excavations could not be confirmed as either that evidence had been removed or the conditions had changed during the previous backfilling and excavation programs.

Because of the lack of critical information available to the team, further investigations and documentation was especially critical for this project to proceed, as well as to provide the detail for projects that may occur in the future to have complete advantage of our finds and understanding of the site and the site features. The thorough documentation of the interventions was also a project priority, the responsibility of the site conservators.

The project team consisted of Dr. Deborah Vischak, Princeton University and Abydos South Project Director, Anthony Crosby, Preservation Architect, and from the Ministry of Tourism and Antiquities, Ayman Mohamed Damarany, Archeologist, Dr. Mohamed Abuelyazid, Archeologist, Hazem Salah Abdullah, archeologist, surveyor Mohamed Gamal and conservators Maroos Mohamed Abdel Fatah, Azza Abd-el ra zek Hassab and Esam Teksh Abo El wafa. Assisting the core team were Reiss Ibriheem Mohamed Ali and his team of supervisors, excavators, and workers. The total number of workers, in addition to the core team, numbered approximately 80-90 during the project.

DESCRIPTION

The Tetisheri Pyramid is 24 meters on each of its four sides and consisted of 47 casemates, or cells, and a corridor leading to a large chamber in the approximate center of the pyramid (Fig. 1). The existing walls were constructed of 40 cm x 20 cm x 10 cm mud bricks, many of which were stamped with the cartouche of Ahmose. At the time of the latest excavation in October 2022 the maximum height of the walls was approximately 2 meters w of the walls were less. There were three basic coursing patterns utilizing widths of either one header, one and one-half headers, two headers or three headers – the three-header walls were the exterior walls, which are corbeled on both the interior and exterior surfaces. The basic coursing pattern of all the mud brick walls is alternating courses of headers and stretchers on the exposed surfaces.

It was determined, based on the physical evidence of the existing exterior walls, both the interior and exterior surfaces, that the slope of the pyramid walls was approximately 62-63 degrees. At 63 degrees the height of the pyramid would have been the same as the base, or 24 meters, and a slope of 2:1 ratio. In February, as the actual program of intervention began, the 63-degree slope was further confirmed on site and with an examination of the pyramidion, which was in storage in an on-site magazine.

Large redeems of broken mud bricks were located on all four sides of the pyramid, the results of the collapse of the pyramid. Many of the interior walls were also deformed, resulting from the collapse of the structure. There is also evidence that the collapse of the pyramid occurred over a lengthy period, as there is sand and water runoff deposited between layers of collapsed mud brick, a condition also reported by Dr. Steve Harvey, the project director during the 2010 excavation project.

An enclosure wall approximately 68 meters by 87 meters surrounds the pyramid proper with an entrance on the east and on axis with the pyramid entrance. It is important to note that the Pyramid was only one component of a plan that extended from the Nile flood plain with the pyramid of Ahmose, the Tetisheri pyramid, located approximately 500 meters to the west, a subterranean tomb farther out near the escarpment and a temple at the base of the cliff, all arranged on an east-west axis. The pyramid is constructed on an approximate 45-degree angle from true north, which is the same basic orientation of the earlier enclosures at Abydos, located 3 kilometers to the north in what is known as the North Cemetery of Abydos, and may represent an ancient characteristic based on the orientation of structures in Mesopotamia.[1]

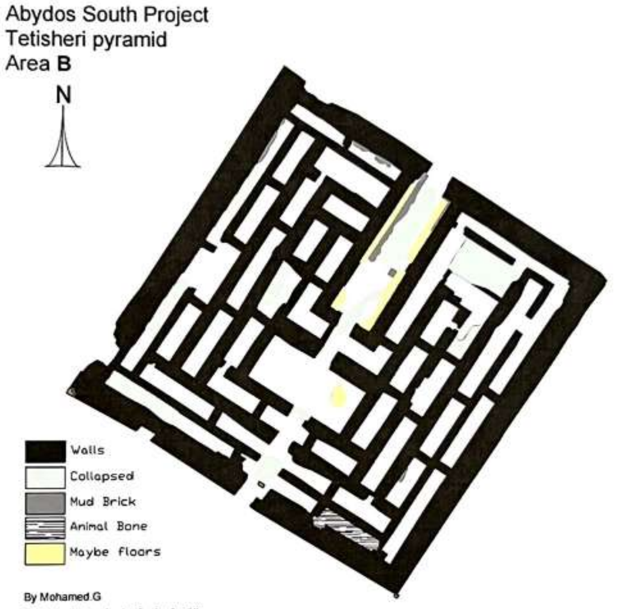

Figure 1: Plan of the Tetisheri Pyramid.
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1. Isler 2001, p.67

1. CONSTRUCTION SYSTEM

The basic construction system consists of interior walls, which formed a grid with shorter intersecting walls constructed to support the major walls – the series of walls forming casemates, or individual cells. The walls parallel to the exterior corbeled walls were only one header in thickness – most of the other walls were 1½ headers thick. As the mud brick walls were for the purpose of supporting the corbeled exterior walls, these thinner walls would not have to be high. The entire system is often referred to as cellular construction system[2]. The system of interior walls supported the exterior casing of mud bricks which were corbeled, supposedly possible for the entire height of the structure . The casemates would have had to be filled to support the interior wall systems. That part of the construction system is clear, i.e., the corbeling of the exterior walls supported by the interior walls, the cells filled with sand as the walls on the interior became higher. Figure 2 Compares a field sketch of the system and an actual restored section of corbeled wall. The space between the main walls was normally between 70 cm and slightly more than one meter.

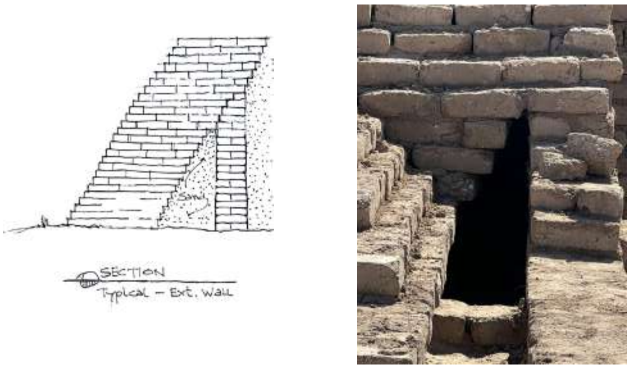

Figure 2: A field sketch of the corbeled exterior wall and the restored detail.
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The cells were formed by transverse mud brick walls, primarily one header in thickness. Several transverse intersecting walls were butt jointed to the main walls while others were integrated into the main walls in the coursing pattern, Typically the integrated coursing wall limited to no more than two courses and interestingly, all the connections were on the side of the main wall nearer the interior. A typical connection between the intersecting walls which connected the two main walls is the brick coursing connection at the juncture with the wall closest to the interior of the pyramid - this was a consistent pattern. A number of intersecting walls had been reduced to one or two courses, some were below the existing grade and were identified by excavations and these were restored.

Several major interior walls were deformed in a reasonably consistent pattern as those that were not plumb leaned from the interior center of the pyramid outward or to the exterior.

The deformation of each wall was not consistent along its entire length, as a section might lean dramatically, while an adjacent section might lean less. Generally, the walls nearer the center of the pyramid leaned more (Fig. 3).

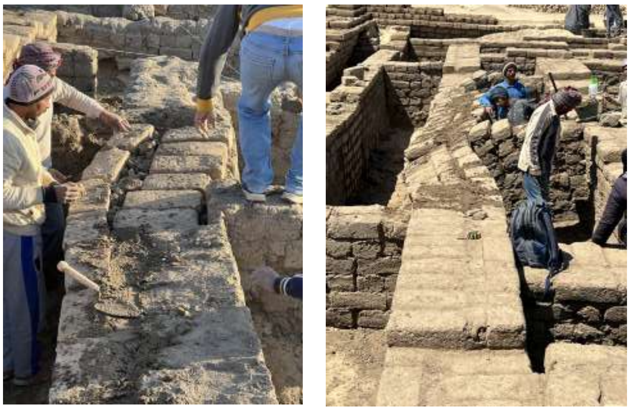

Figure 3: Two deformed walls stabilized with the existing characteristics.
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Because of the deformation of the interior walls, it has been suggested that a series of arches were also used to support the exterior mud brick corbeled walls as some sections of the leaning walls suggested the beginning of an arched structure[3]. However, we found no unambiguous evidence of arches or vaults as part of the structural system. If a particular wall is the lower part of a vault, a consistent pattern along the length of the wall would be expected, and as pointed out above, that was not the case. However, the subsequent stabilization of these walls reflected the existing geometric character and does not negate another interpretation. Two primary interior spaces, the corridor and the inner chamber had to have been roofed, but no specific evidence was found to support either flat roof or vaulted roof systems.

Continuing excavations by the project archeologists found no evidence that the site had been leveled prior to construction. The ground slopes up from east to west and the bases of both the north and south walls stepped up four courses from east to west to accommodate the grade. The east wall also steps up by two mud bricks from south to north and these base courses were laid directly on sand or the natural base, a conglomerate of sand and rocks.

The exterior walls are corbeled on both the exterior and interior surfaces. To achieve the slope of 63 degrees, each successive course is stepped back 6-8 cm. The slopes of the weathered surfaces of the exterior vary somewhat because of differential weathering; in several locations the entire outer course was eroded and what remained were the headers which formed the interior. However, it seemed clear that the exterior bricks were not shaped to the overall slope and although none

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[2] Arnold 2003, p 49

[3] Harvey 2010, p. 3, p. 6.

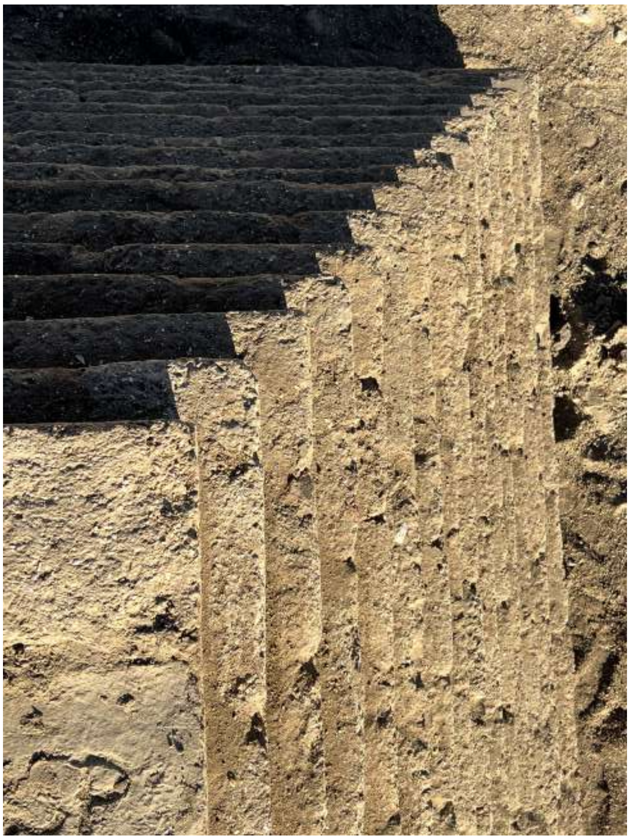

Figure 4: Northeast corner showing the stepped courses in view from above.
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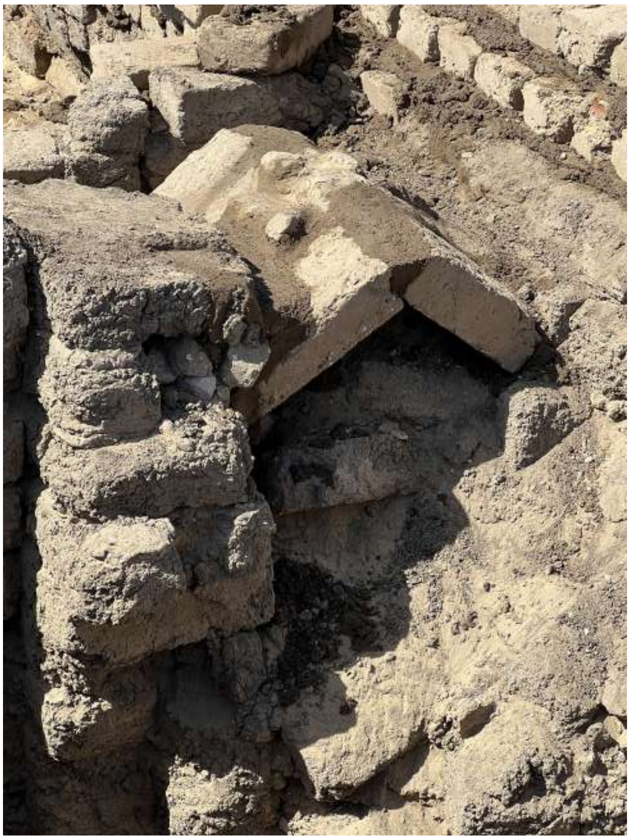

Figure 5: A feature spanning a cell that was stabilized.
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existed *in situ*, it is assumed that the recessed space formed by the successive courses would have been filled with plaster (Fig. 4). There was no evidence of any actual casing on the exterior.

Investigations continued during the project and reuse of the structure later in its history became clear, as several burial pits were found. Two cells, one on the north wall and another on the west wall appear to have been converted to accommodate, in one case a human burial and in another case for an unknown function. In these cases, a simplified mudbrick system to span a space of approximately 60 cm was used. This feature was conserved in place without altering its relationship to other adjacent features (Fig. 5).

The number of mud bricks used for the construction was estimated during the project – the actual number of mud bricks remaining in the construction rubble was also estimated and mud bricks were probably salvaged for reuse in the area as the estimate of remaining bricks is considerably less than the number needed originally. There is other evidence of reuse as artifacts from later periods were also found at the site[4].

2. CELLULAR CONSTRUCTION

The immediate precedence for the cellular construction of the pyramid is the casemate construction of the North and South Palaces at Deir el Ballas from the second intermediate period or immediately prior to the 18th dynasty and Ahmose's reign[5] However, the concept of structural systems consisting of walls creating cells which are filled to supply lateral support is much more ancient. Dieter Arnold describes mud brick pyramids from the Middle Kingdom with a grid of brick walls with the spaces between filled with sand and rubble[6].The 5th dynasty mud brick pyramid at Lahun had a series of interior stone walls with the spaces between filled with mud brick masonry[7]. Badawy also refers to similar limestone grid systems[8]. Dieter Arnold also refers to this as "core construction," described as the structural interior of mastabas and pyramids being stabilized by interspersing the fill with radiating walls of stone[9]. While sharing a basic construction concept with the casemate structures at Deir el-Ballas and in Nubia and the delta area immediately preceding Tetisheri, these were all constructed as platforms to support superstructures; consequently, the casemate walls were limited in height. At Deir El-Ballas the tallest walls of the North Palace are 5 meters[10]. This basic construction system, casemates forming a base for a structure built on top and was one of the most characteristic features of Egyptian architecture of both the 1st millennium BCE and the following Roman period[11]. The Tetisheri Pyramid construction appears to take this concept to the next level in forming not just a platform to support a structure but the basic construction system for a pyramid to a height of 24 meters (80 feet).

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[4] Harvey 2010, p.7.

[5] Małecka-Drozd 2014, pp.149-153.

[6] Arnold 2003, p. 87.

[7] Spencer 1979, p. 37.

[8] Badawy 1966, p. 101.

[9] Arnold 2003, p. 60.

The limited height of the remaining mud brick walls of the Pyramid restricted our complete understanding of the construction of the upper construction system. We could assume the interior mud brick walls continued to the full height of the pyramid, but there could be other interpretations as well. Perhaps the grid of mud brick walls was reconfigured as the height grew - we simply do not know. We do know that there were adjustments made during the construction as it appears that there were construction problems resulting in a partial collapse in one area and the addition of a more massive mud brick feature constructed on collapsed mud brick. It was also clear that the pyramid deteriorated through a series of collapses that probably occurred over hundreds if not over several thousand years.

3. CONSERVATION PROGRAM

The goals of the conservation program were to protect the remaining original materials and systems, to protect evidence of later uses of the structure and to restore features that reflect the significance of the structure. We must remember that most construction throughout the Pharaonic period was of mud brick. As with other types of Egyptian architecture, those of stone were less subject to weathering, consequently, were more permanent and more examples remain of stone structures. We know that early dynasty pyramids were constructed of mud bricks and the use of mud bricks in the construction of pyramids increased, but because of their more fragile nature, few remain[12]. The Tetisheri Pyramid is a unique structure, and the team was given a valuable opportunity to be able to present the construction systems as we understood them and to protect components of the construction systems that could be interpreted in other ways.

The initial phase of the project was to stabilize the existing mud brick walls by repairing undercut walls, by applying a protective top course to the fragile mud bricks, and by filling holes and missing wall components with new mud bricks. The pattern of leaning walls which became deformed by the stress of decay and collapse and the characteristic of failure was a vital feature to preserve.

Additional excavation began along with the initial stabilization efforts. Additional cells had to be cleared for the work to proceed to investigate previously identified animal mummies, possible human burials, and the evidence of the collapse of the upper parts of the pyramid. As one cell for which stabilization work was required, the removal of a layer of sand revealed a mud tablet 60 cm by 60 cm with stamps of the cartouche of Ahmose. Stabilization work was redirected to another area while the tablet was studied in situ and eventually removed. Additional excavations in the area of the tablet revealed a pit tomb which could have preceded the building of the pyramid. This was just one of several shallow pits in and near the pyramid that are suspected to be earlier burial pits.

The friable and deteriorated mud bricks on the top wall surfaces were removed and replaced with one or two courses of new mud bricks. The existing heights of the walls were maintained as the new mud bricks stepped to follow the existing wall heights Missing wall sections were restored to define the cells (Fig. 6).

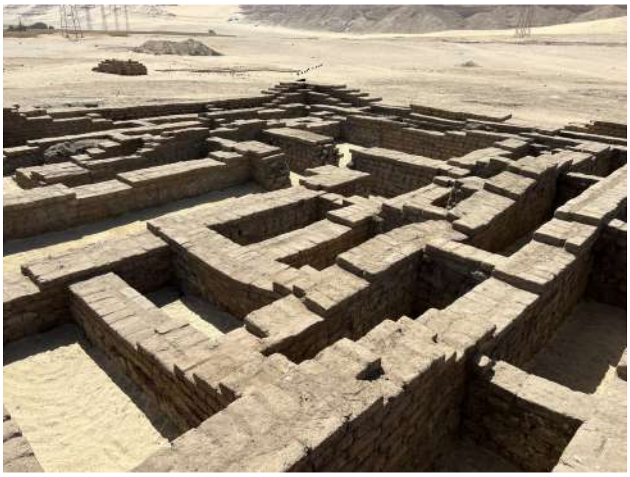

Figure 6: Existing walls, stabilized walls, and restored walls in the north section of the Pyramid.
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The actual stabilization work was completed during the second week of field work and the restoration phase began, which consisted primarily of adding additional courses to the four corners, further defining the entrance area and constructing three interior walls that had been partially destroyed by trenching to reach the interior of the structure at an unknown time in the past. The corners were in the worse condition and determining the actual corner required additional clearing and excavations and precise surveying. Once the exact location of the corners was determined, mud bricks courses were laid to define the corners more clearly. A wood templet was fabricated to ensure the original slope of 63 degrees was maintained. The final height of the corners, which became the tallest part of the restored structure are currently between 1½ and 2½ meters. The structural characteristics of the interior walls were maintained including the existing coursing patterns and more importantly, the actual condition resulting from millennia of use, neglect, and decay. Where stabilization was necessary, the actual geometry of the existing walls and features was maintained. See Figures 3 and 6.

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[10] Lacovara 1990, p. 2.
[11] Małecka-Drozd 2014, p. 151.
[12] Badawy 1966, p. 87.

Where possible the exterior walls with the actual pyramid slope were maintained and in other cases, the exterior walls were protected with new mud bricks. The process involved in deciding when original walls were to be exposed and when they would be encased with new mud bricks was one of the most difficult decisions of the entire conservation process. Figure 7 shows both conditions and how they were treated.

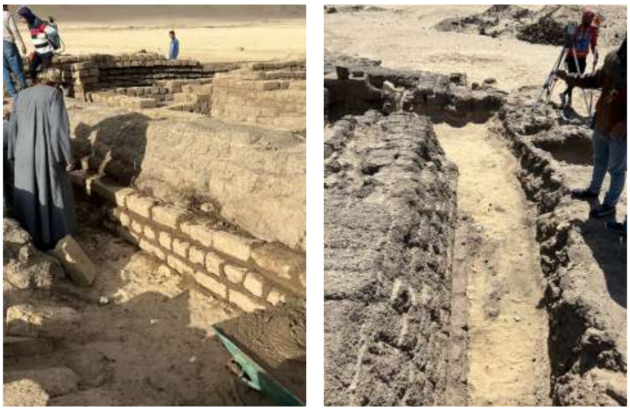

Figure 7: Two sections of the exterior corbeled wall, one left exposed and one encased in mud bricks.
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The footprint of the south half of the corridor entrance was clear and there was enough evidence to understand the relationship of the vertical portion of the doorway surround and the adjacent sloping walls. This relationship was important to show clearly. Figure 8 is of the restored entrance from the southeast.

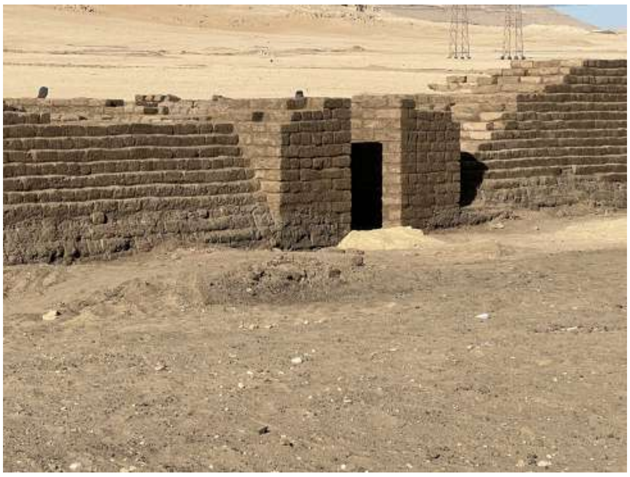

Figure 8: The restored corridor entrance to the pyramid.
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One of the last steps in the project was a light texturing of the exposed surfaces of new bricks. The difference between the original mud bricks and the new mud bricks is obvious, primarily because the color of the new bricks is more the color of the desert sand and are warmer than the original bricks. The weathered texture of the original bricks was also distinctively different than the new bricks and the light texturing of the new bricks made the visual contrast less (Fig. 9). The difference in color and texture also depends on the intensity of the ambient light as well as its direction, relative to the wall surfaces. This was considered during the final texturing of the bricks. The last step before the end of this season's work was the removal of debris of broken new bricks and spoil heaps and the filling excavated areas and the cells with sand. The ground level was returned to its approximate position prior to any excavations. The historic deposits of collapsed mud bricks both inside and outside the pyramid were left as they were found. The site was then cleaned of construction debris, depressions and holes were filled with sand, approximately 30 cm of sand was placed in each cell to protect exposed surfaces and the grade was brought to what we estimated as the historic levels. The cells along the perimeter of the four sides were filled near the top to provide stability and safety for the corbeled exterior sloped walls.

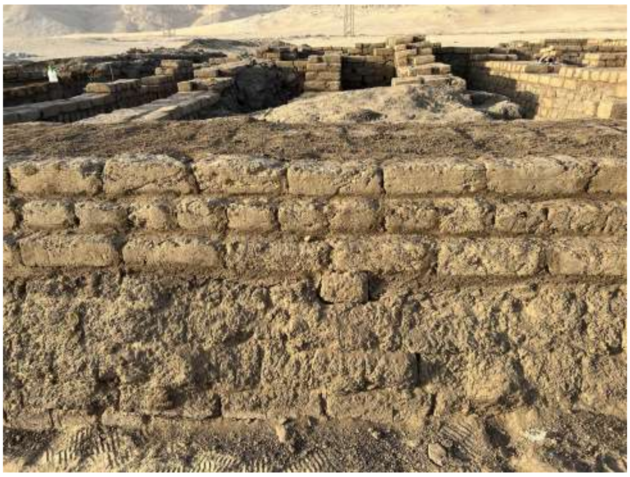

Figure 9: A typical example of an original mud brick wall with courses of new mud bricks, some of which have been textured.
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CONCLUSION

The Tetisheri Pyramid is a unique structure, and the entire team understood the significance and the important values and what was required to protect and enhance those values. We believed we were gifted with an opportunity to interpret the actual construction system and to a lesser degree, the process by which it deteriorated over the 3500-year history of a structure and a structural system. These were the most important values. While there remains work to do, this overall goal of being able to present these important values for the appreciation and understanding of those who visit the site we believe are correct. There were discussions throughout the project about the degree of restoration that was appropriate and while those discussions ranged from documenting and back filling the site to a total restoration of the pyramid to its full height, the team believed the approach taken is the correct one. Figure 10 is a before and after comparison of the Tetisheri Pyramid prior to the conservation interventions and near the end of the project.

The project continues to be evaluated and additional interventions will be required in the future to properly interpret and present the significance of the unique structure. Additional projects will include additional mud brick work to raise some of the corners more, to protect original material mud brick material, to restore the corridor floor, to determine and restore the actual doorways from the corridor to the inner chamber, to restore the enclosure walls and most importantly, to develop a site master plan, an interpretive plan with associated interpretive signs and other materials.

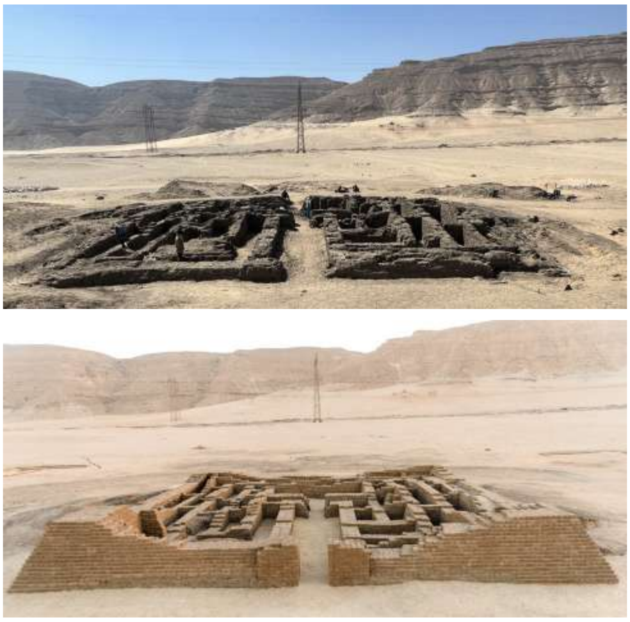

Figure 10: Before and after comparison of the work accomplished in this 2023 fiel season of four weeks.
© A. Crosby (on top), A. Damarany (on bottom)

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CONSERVATION OF THE EARTHEN ARCHITECTURAL ASSETS AT PEPY I NECROPOLIS ARCHAEOLOGICAL SITE: HOW TO ADAPT TO CLIMATE CHANGE?

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SUMMARY

During March 2020, Saqqara was subject to an unprecedented spell of heavy rainfall that affected most of the earthen archaeological remains present at the site. As part of the Nile's Earth ANR funded project, a series of missions were carried out at the site in November 2021 aiming at suggesting and possibly starting to implement specific experimental measures that could improve upon the conservation practices already in place at the site for several years.

This paper first describes the Pepy I necropolis and the specificities of the earthen assets present at this archeological site. It then summarizes the results of the overall condition survey and risk assessment made in 2021, including a critical analysis of some of the previous conservation techniques applied on these structures and, as a result, the justifications for the choices of the first corrective measures which were implemented. It finally covers the first results observed, including after the site had received further heavy rain before the end of 2021, and explains the proposed research activities to be implemented in the future.

INTRODUCTION

During March 2020, the Saqqara world heritage site was subject to an unprecedented spell of heavy rainfall that affected most of the earthen archaeological remains present there. As part of the Nile's Earth project funded by ANR (Agence Nationale de la Recherche), in November 2021 a mission was carried out at the Pepy I necropolis, which is under the custodianship of the Franco-Swiss Archaeological Mission of Saqqara, one of the operational partners of the ANR project. This mission aimed to perform the first overall evaluation of the impacts resulting from the heavy rainfall, and to launch a long-term response to the possibility of similar rainy events in the framework of the global climate change process.

Rather than a detailed condition survey, the methodology was oriented towards making sure that the causes, circumstances, and processes of decay could be identified and understood, in some instances even though the conservation works and protective measures which had been implemented in the past.

This first assessment led to the proposal of some initial corrective measures that could be implemented immediately during the ongoing archaeological campaign, as they were mainly adaptations of existing restoration techniques. Furthermore, in November 2022, a second mission allowed further observations, the implementation of a new set of preventative measures at some of the structures involved, and the launch of an exploratory process to improve the capacity of the mud bricks used for the restoration of the most exposed parts of the archaeological structures.

This paper provides an overall description of the works implemented, the first results observed, including after the site having received a new heavy rain, by the end of 2021, and what are the proposed research activities to be implemented in the future.

1. BRIEF PRESENTATION OF THE PEPY I NECROPOLIS

Excavations at the necropolis of the royal family of Pepy I have been conducted for several decades by the Franco-Swiss Archaeological Mission of Saqqara[1]. The site was first occupied in the reign of Pepy I (± 2250 BC) and was then used discontinuously until the end of the Middle Kingdom (-1800) and the Late Period (650-332 BC).

This necropolis benefited from a particularly intense occupation, which was probably the densest and longest of the Old Kingdom[2]. Having been used by several generations, reaching well beyond the reign of Pepy I, it represents a unique case of special interest and thus is highly suitable for the study of the evolution of a royal necropolis. The excavations have also provided archaeological evidence of its uniqueness since it is presently possible to follow the evolution of the necropolis from the reign of Pepy I through until at least the Middle Kingdom[3]. The royal necropolis of Pepy I (Fig. 1) is organized according to a master plan which uses concentric circles to clearly distinguish the different social strata from the king at the centre, and the rest of society distributed around him, in order of importance. The distribution is simple and the placement of the dead in the necropolis follows the social order of the living.

In terms of organization, the funerary complex dedicated to the king (pyramid and funerary temple) is delimited by a large 4m wide enclosure (1st circle)[4]. A 5 m wide street runs around the enclosure. This street serves all the funerary complexes of the royal family (royal wives and children) which are established all around the king, thus forming the 2nd circle. The various funerary complexes of queens which have been excavated to date in the Pepy I necropolis present more or less complex profiles and contours, reflecting the chronological evolution of their establishment, and taking into account previous additions.

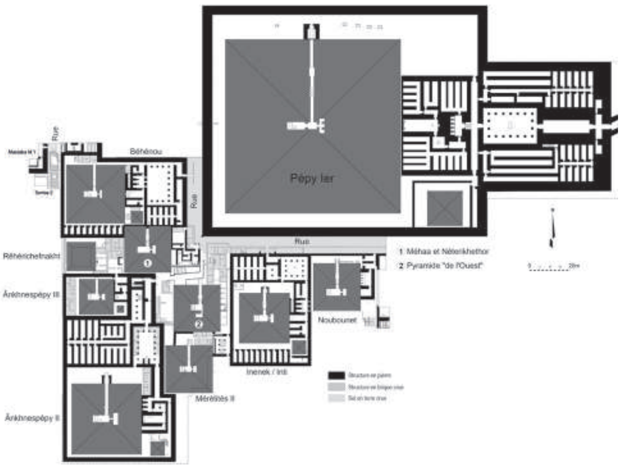

Figure 1: General plan of the Pepy I necropolis.
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Lastly, the necropolis of the elite is established behind the royal family, constituting the third and final circle. The plan of the necropolis, as it appears today, allows us to partly identify the western limit of the second circle: the western enclosures of the complexes of queens Ânkhnespépy II, Ânkhnespépy III and Béhénou have a perfect rectilinear alignment which is oriented on a north-south axis, demonstrating the planned distinction between the necropolises of the royal family and of the high dignitaries. Moreover, a street similar to that separating the king from the queens runs along the western side of this wall, providing access to all the mastabas in line.

2. EARTHEN STRUCTURES AT THE PEPY I NECROPOLIS

Within the Pepy I necropolis, several types of materials were used for the construction of the monuments: stone, of different qualities and origins (local limestone and from the right bank of the Nile, Aswan granite, Egyptian calcite or alabaster, quartzite, basalt, and so on), wood (cedar, sycamore), and raw earth. The latter has a secondary place in the necropolis, but its use was not negligible; indeed, a quick calculation allows us to estimate earth to have constituted 15% of the surface covered. We can distinguish several types of built structures, from the most massive and complex to the lightest that do not require significant technical knowledge for their construction. To describe them, we have built a typology specific to the site:

a) Mixed constructions (stone/brick)

These stone and brick materials often form the core of structures faced with limestone. To illustrate these cases, we can cite as examples the complex of Queen *Méhaa* and her son Prince *Hornetjerikhet* (Fig. 2) and Tomb No. 2 (excavated in 2022), the main parts of which are made of bricks, with the outer walls covered with limestone "slabs".

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[1] The MafS was founded in 1963 by Professor J. Leclant, with the assistance of J.-Ph. Lauer, and was directed until 2007 by Dr. A. Labrousse. It became the Franco-Swiss Archaeological Mission of Saqqâra and is now the responsibility of Ph. Collombert, Professor at the University of Geneva. A website dedicated to the work of the mission is available online at: https://mafssaqqara.wixsite.com/mafs.

[2] The fame of this necropolis was such that the very name of the pyramid of Pepy I, "*Mennefer*", was used to designate the ancient capital of the country, Memphis, nearby, from the end of the Old Kingdom.

[3] All the annual reports published in the section "Fouilles et Travaux en Égypte et au Soudan" of the journal *Orientalia* are now available online. Having also benefited for many years from the patronage of the Académie des Inscriptions et Belles-Lettres, the MafS regularly presented the results of its work in its "Comptes-rendus" (Labrousse & Leclant 1998, 2001, 2006; Collombert 2011). Since 2020, the annual reports have been presented in the *Bulletin archéologique des Écoles françaises à l'étranger*, an online journal (Collombert *et al.* 2020, 2022, 2023).

[4] The entire funerary complex of King Pepy I has been published: Labrousse 2019.

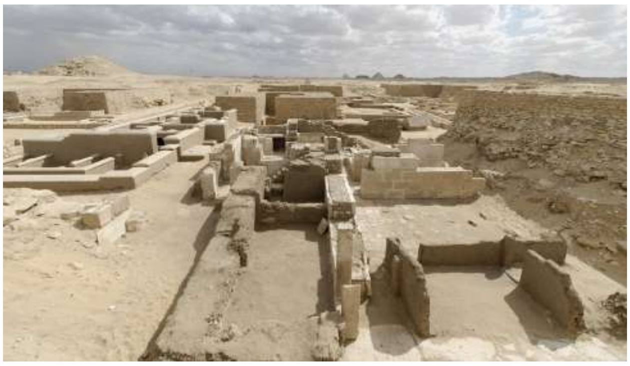

Figure 2: Funerary complex of Queen *Mehaa* and her son Hornetjerikhet (right), and the anonymous "Pyramide de l'Ouest" (left); use of massive brick walls and mixed constructions.

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b) Brick structures
Structures built entirely of brick are the most common. They are found in the following forms:

- large modules, such as elements of funerary temples (pyramid "of the West" in the Old Kingdom; the *Rêhérichefnakht* complex in the Middle Kingdom), or tombs built either in the necropolis of officials to the west (between *Béhénou* and *Ouni*) and to the south (south of *Noubounet*) of the complexes of the queens, or within the 2nd circle;
- small buildings whose walls rarely exceed 2 to 3 bricks in thickness; they are poorly preserved, and only remain in the form of a few sometimes disjointed courses that do not stand up well to exposure to the open air after excavation (Fig. 3). They are mostly installed in constrained spaces that were originally either uncovered (e.g., the northern peribolus of the queens, small spaces between the pyramid and the storerooms, against the façades of the complexes of the queens, etc.), or partially covered (porticoes of the pillared courtyards).

c) Materials used in floors and for earthen plaster
Many of the buildings described above contain earthen plaster which is sometimes covered with a layer of gypsum. The floors are also very often covered with a layer of earth mixed with small pebbles and/or cobbles[5]. These were used in the construction of the streets and the setting of the floors of the buildings' rooms, even when the latter were laid on limestone paving (Fig. 4).

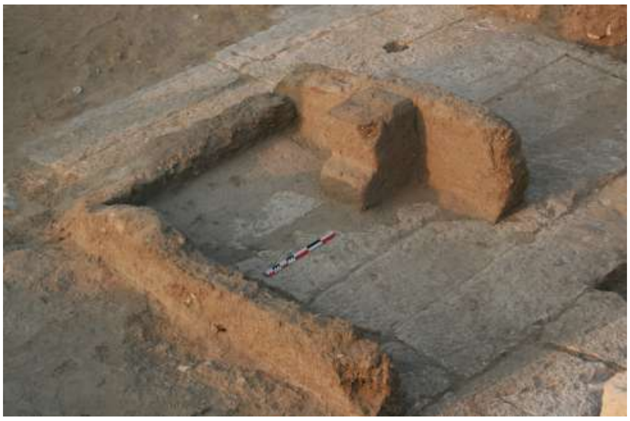

Figure 3: Queen *Behenou*'s complex: small mudbrick building discovered north of the pyramid. Construction of one to two bricks thick covered in places with a gypsum coating.

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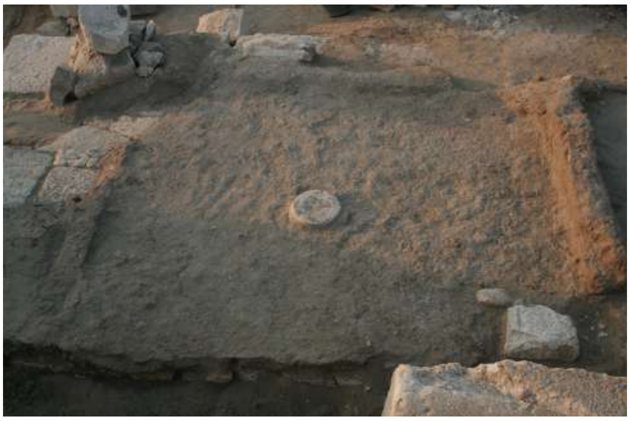

Figure 4: Queen *Behenou*'s complex: small mudbrick building erected in the courtyard north of the pyramid. An earthen floor was laid on a pre-existing pavement.

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3. CONSERVATION EFFORTS REGARDING THE EARTHEN STRUCTURES OVER THE LAST 30 YEARS

For many years, the MafS has had a mission to enhance and protect all the structures uncovered during the various excavations, whether they are made of stone or mud brick. For the latter, we have identified three main and complementary methods, all of which have been implemented on the site (Figs. 5-6):

Method A: partial reconstruction of the walls with identical mud bricks made with local materials; the earth as well as the straw and degreasing agent (limestone chips and pebble fragments) are taken from the silt at the nearby village.

Method B: covering the faces of the structures with earthen plaster made according to traditional methods; a particular aspect (such as traces of smoothing) must make them easily distinguishable from the original elements.

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[5] These elements, locally called *zalat*, come from the underlying natural terrain in the form of more or less thick terraces covering the limestone.

Method C: covering the wall levels in order to protect the tops of the walls with "caps"; first, the structures are completed in order to create a rectilinear top with bricks (method A); when the wall is several rows thick, only the outer courses are rebuilt while those constituting the core are replaced with a filling (fragments of limestone, bricks and earth combined). Finally, the "caps", made with modern fired bricks bound with lime mortar, are mounted in an overhanging position, and covered by a semi cylindrical shape made from the same mortar mentioned above.

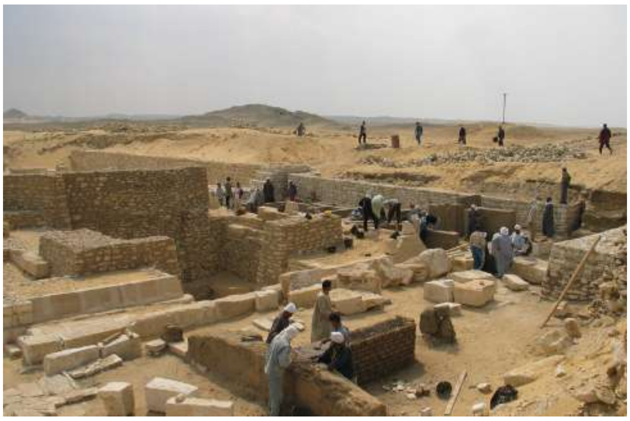

Figure 5: Conservation works on the mudbrick structures (methods A and B).
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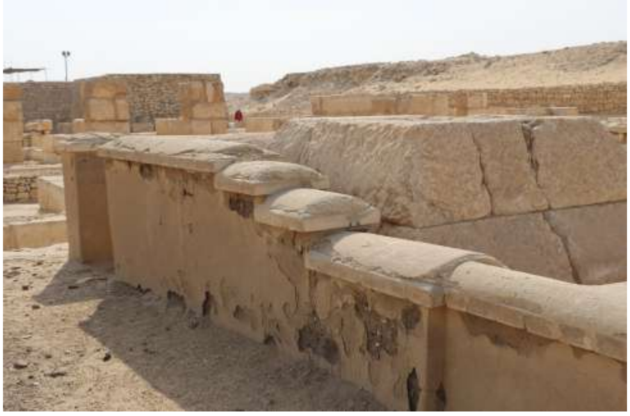

Figure 6: The conservation works (method C) did not prove efficient during the 2020 rains.
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Critical observation of the listed methods: advantages and disadvantages.
The use of materials identical to those of the heritage assets (method A) maintains a certain aesthetic cohesion throughout the site. Nevertheless, erosion eventually damages the structures, and many overlaps are caused by drips, especially due to rainfall. In concrete terms, the old and the new coatings mask each other, making it difficult to distinguish between the original and the conservation coatings.

The presence of rendering (method B) protects the faces of the walls which are most exposed to bad weather (rain, and also very erosive sandy winds). However, time and climate bring degradation, which requires regular intervention by the masons on the damaged structures. This, in turn, implies the permanent presence of a team of qualified workers during each season of excavations to ensure both the maintenance of the site and the restoration of new structures which are brought to light.

In combination with methods A and B, method C effectively protects the tops of the walls, and the overflow pushes the runoff beyond the wall. Unfortunately, the Antiquities Service has often reminded us of the lack of aestheticism of this choice, which we have therefore had to replace as best we could for several years. This represents a great deal of work for the Mission, as this method had become systematic in covering all brick walls since the 1990s. Over time, there is a natural tendency for the "caps" to fall off, resulting in infiltrations between the disjointed bricks, causing cracks in the heart of the walls and the plaster to detach. The main consequence is that the walls "open up" following vertical cracks to the base.

4. THE HEAVY RAINS OF MARCH 2020 AND THEIR IMPACT

On May 4, 2018, Egypt Today warned that: "As Egypt's climate changes, heavy rainfall is becoming more and more common, bringing dangerous flash floods. Flash flooding can make the dry ground become saturated in an instant, allowing torrents of water to rush down mountains like a waterslide, wiping away cities"[6].

Though official reports on climate change like the recent one published by the World Bank (World Bank Group, 2022) mostly concentrate on the risks linked to coastal flooding due to rising sea levels, it is now recognized that "coastal rainfall... will cause more frequent and intense flash-flood events in Egypt…".

This scenario is what happened in Saqqara in 2020, with heavy rainfall on 12, 13, and 16 March. Though Saqqara may have been affected in a slightly different way due to its location on top of a plateau, 40 m higher than the plain, the data from Cairo airport provides a good idea of the rainfall that occurred. Geoclimat website[7] reports that: "In Egypt, 64.7 mm fell in 2 days on March 12 and 13 at Cairo airport (including 45.0 mm in 24 hours, a record), i.e., the equivalent of more than twice the average annual rainfall (25 mm/year [24.7 mm according to the 1971-2000 average and 26.0 mm according to the 1961-1990 average]) and 16 times the average monthly rainfall (4 mm) for the Egyptian capital!".

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[6] https://www.egypttoday.com/Article/1/49307/On-climate-change-11-Egypt-s-governorates-vulnerable-to-floods

[7] http://www.geoclimat.org/2020/03/egypte-precipitations-12-13mars2020.html

In such conditions, it is not surprising that the measures previously taken to protect the earthen structures present at the Pepy I necropolis which had been adequate in the past proved insufficient, leading to numerous instances of damage. Observations made in November 2021 included the following:

At the top of the walls: the flat shapes lead to the formation of gullies, the extent of which varies greatly depending on the shape and surface of the rainwater collection area. The joints between the bricks, especially those positioned as a stretcher, are areas of weakness. Concrete protective caps (method C) that had already been criticized for their poor aesthetics by the Egyptian authorities have also proved insufficient, if not leading to specific types of erosion, just underneath them (Fig. 6).

On the faces of the walls: The western and northern facades appear to be the most affected, but the erosion is quite minimal. The southern and eastern elevations are only affected by gullies from the top. Besides that, deposits are brought by the flows from the tops of the walls.

At the bases of the walls: erosion in the form of "destructive furrows" exists in zones prone to runoff and / or water stagnation. These instances of erosion are very important where damp is retained by sand or powdery earth deposits on the surrounding ground. Wall (and floor) configurations on stone slabs are also very unfavourable (Fig. 7).

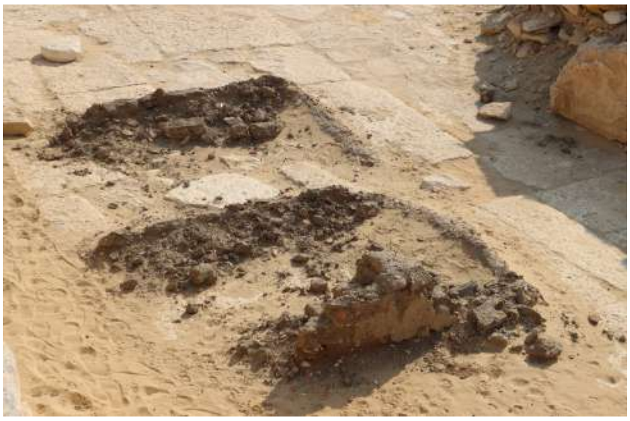

Figure 7: The small structure (see Figure 4) built right above stone slabs suffered badly in 2020.

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Finally, sand accumulation can be high, particularly on the western side of the necropolis which is the most exposed to wind. This sand absorbs the rainwater and it remains for a long time. Sixteen months after the heavy rains, damp was still present at the bases of the walls, with an impact as described above when the height of the accumulation is different for the two sides of the wall.

5. DIAGNOSIS AND RECOMMENDATIONS MADE TO ADAPT TO CLIMATE CHANGE CONDITIONS

The diagnosis of the state of conservation of the earthen structures at Pepy I was performed based on observations made on the structures present at the site itself, but also on some other reference structures at sites also located at Saqqara, mainly the *mastaba* of the first dynasty (North of Djoser pyramid) and the tombs of the New Kingdom necropolis (south of the Djoser pyramid).

To that end, rather than a detailed condition survey, the methodology was oriented towards building an overall understanding of the behavior of the earthen structures present at the site during the spells of heavy rain, through identifying signs of decay, and ensuring that the causes, circumstances, and processes of decay were identified (Joffroy, Moriset 1996) so that, where possible, corrective measures could be proposed. A multi-scale and multi-level approach was adopted, starting from the site itself and further zooming in to examine individual structures and their fabric at the top, elevation, and plinth levels. In that respect, the first important asset studied was the topography of the site. Located 40 m above the plain, the site is almost totally free of any vegetation, which indicates that no damp rises from the water table, and as such, there is no presence of salts.

Thus, the main threat to be considered here is water originating from rainfall, a subject on which numerous studies have been done since the 1990s (Houben *et al.,* 1990; Bendakir, 1999).

On the walls themselves, the phenomena observed starts at the surface of the wall which has the initial potential to absorb the first drops of water. When the surface is saturated, there is a continuity of absorption inside the structure (possibly including through micro cracks), but this is also when the water accumulating at the surface starts to flow. That process always starts at the top of the wall as it is more exposed, though if the rain is accompanied by wind, then the exposed elevations can be prone to a similar phenomenon. The main issue, then, is that the water accumulating on the top surface of the wall finds a way to flow down to the vertical surfaces. How this happens depends on the regularity of the top surface, but it is clear that even if the top of the wall is flat, it is never flat enough to ensure that the flow of water is equally distributed. That issue leads to the creation of concentrated flows which, if the rainfall lasts long enough, results in the erosion of the vertical faces of the walls in the form of gullies. An important point here is that the thicker the wall, the more water is collected, and thus the deeper is the gully formation (Fig. 8).

When heavy rainfall occurs, water flows down the walls towards ground level, where it joins rainwater which has

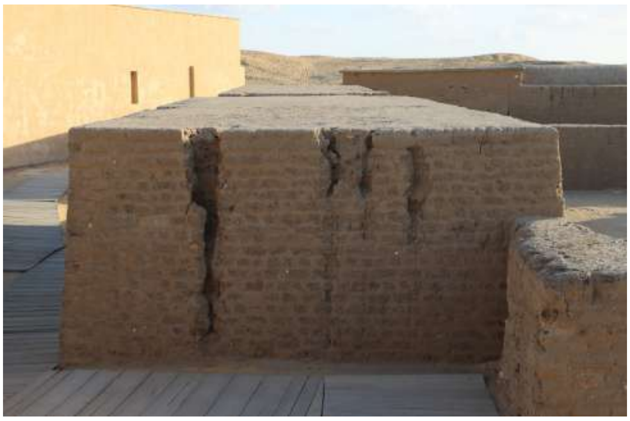

Figure 8: Gullies formed on a recently partially reconstructed entry pylon of one of the tombs of the New Kingdom necropolis at Saqqara.

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fallen directly on the ground and has not been absorbed. Additionally, there is the potential presence of runoffs from the nearby environment. Almost always at archeological sites, the presence of debris pits all around tends to create “funnel effects”, that often result in “swimming pool effects”. In such circumstances, wall bases become humid and lose their bearing capacity, resulting in the leaning out of the structures and further collapse, thin walls being more quickly affected than thick ones. At the Pepy I necropolis, two factors aggravate this process. The first of these is that some of the courtyard floors are paved with stones, with little capacity to absorb water, though it should be noted that around the main pyramid, the original pattern of the stone paved floor is that it had been levelled to ensure drainage towards exits and drainage pits. The second aggravating factor is the presence of sand deposits (brought by wind) that keep the humidity high, and thus also keep the walls wet.

Additional threats with minor or isolated impacts come from the presence of animals at the site, mainly dogs, who dig cavities in which to rest at the bases of some walls (the north side as it is fresh), and a few birds trying to establish their nests in the structures.

6. NEW RESTORATION TECHNIQUES IMPLEMENTED OR BEING TESTED

Considering both the existing evaluation of the former achievements and this detailed diagnosis, it was agreed that reflection should focus on improving solutions A & B described in part 3 of this article, and testing revised or complementary ones that would reinforce the prevention of damage at the site (Joffroy, 2012).

Capping

For the better protection of the walls and their plaster from rain damage, it was agreed to test rounded shape capping. This capping has three main advantages when compared to a flat surface. First, it represents a huge mass at the top of the wall, with good capacity to absorb substantial amounts of rainwater. Second, a rounded shape favors the partition of water flowing down towards the wall faces, thus greatly limiting the possibility of flow concentration, and therefore, the formation of deep gullies. Third is that by providing a mass of earth at the top of the wall, the phenomenon that occurs during limited rains - of the transfer of matter from the top of the wall towards the vertical surfaces - is favored, repeating on these occasions the process of formation of a thin protective plaster-like layer.

To keep the changes reasonable in aesthetic terms, the first experimental capping that was realized at the site was limited in height, and to make the process quick and easy, the shape was designed to be obtained simply by laying bricks on the edge and by modelling plastic mortar. The finish is obtained with two coats of plaster, the final one being flush with the plaster layer of the wall faces (Fig. 9).

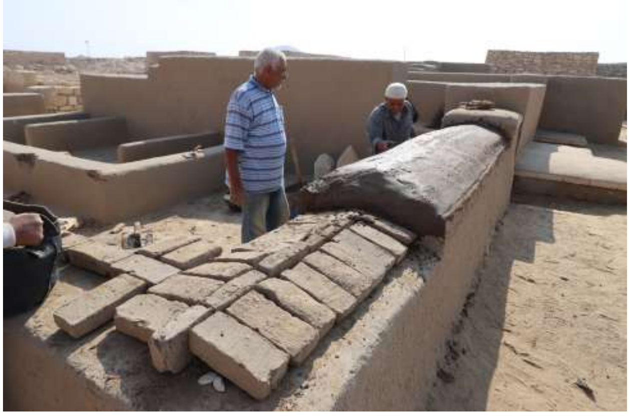

Figure 9: Rounded shape forming the protective capping prepared with bricks and two coats of plaster finish.

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Protection of wall basis

To avoid the possibility of water stagnating by the sides of the bases of the mud brick walls, a scenario that would endanger their stability, the test zone (Méhaa complex) was studied to identify its potential “natural” slopes. The idea was to install a drainage system that drives the water towards potential superficial drainage canals or existing ancient drainage pits. Zones where water could stagnate far from the wall bases were also identified. The response here was to first clean the debris and then undertake a ground (or floors) levelling with slopes of approximately 5cm/m towards either the center of the rooms or areas which could serve as superficial drainage canals. Where a stone wall basis was present, the cleaning was done in a way which would ensure that this original protective measure would be recovered on at least 10 cm high (Fig. 10). That was possible at places where the ground (floor) is made of compacted earth (or debris). But, there are also numerous places at the site where this system will not be possible due to the presence of flat stone floors, which is why an additional experiment has been launched.

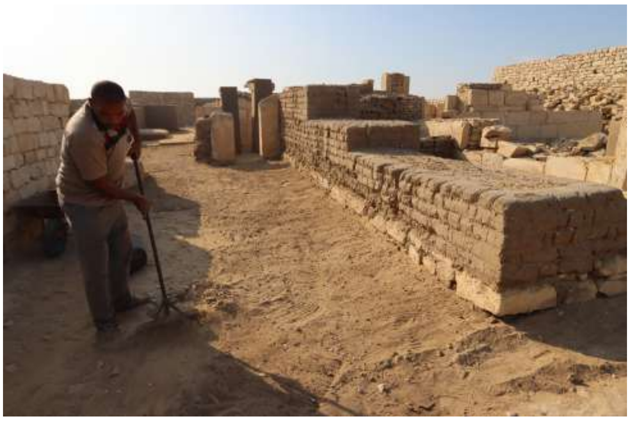

Figure 10: Levelling of the ground around the structures for proper drainage and the recovery of the stone wall basement.
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Alternative wall basis for stone floors
An unfortunate but clear pattern at the Pepy I necropolis is that when heavy rains occur, the capacity of mud structures built on stone flooring systems around the main buildings (pyramids or mastaba) to cope with the water is very limited. Several structures that had withstood several years without problems were seriously affected during the 2020 heavy rains, to the point that it is now difficult to restore them except by rebuilding them as they were documented when brought to light. This limited reconstruction is ethically possible, but there is also the opportunity to propose a reconstruction using more resistant materials, at least for the first one or two rows of bricks, which are most at risk. The way to do that is known as stabilization (Doat *et al.,* 1979), though how to undertake it to create and use mud bricks with compatible aspects / colors requires experimentation. To that end, a first series of samples were prepared using the locally available soil with the following additives: cement, white cement, lime, and gypsum (Fig. 11). These samples will be tested next season, primarily through a cycle of capillarity tests to check the capability of the bricks to withstand a temporary humid state.

CONCLUSION AND THE WAY FORWARD

Pepy I necropolis has been excavated for more than 50 years. Through time, the need to conserve the unearthed structures arose, and works were implemented with a specific focus on earthen structures that were more affected by the rains than the stone structures. Through that process, a variety of solutions were suggested and implemented with results that appeared satisfactory, though one of them, thought to be more durable, was criticized as too intrusive. Interestingly, this latter solution did not work well during the heavy rains that occurred in 2020. In response to what appears to be the result of climate change (such heavy rains have tended to become more frequent in recent years in northern Egypt), solutions need to be found which are both visually satisfying, and meet maintenance requirements.

The sample restoration works implemented to date have already received substantial amounts of rainfall. Their behavior has been quite good; however, as the rains were not at the level observed in 2020, it is too early to assess the advantages and the limits of these solutions. Additional experiments are planned, but more work will need to be implemented in the future to draw conclusions and possibly extend applications. To that end, there is a definite need to find a proper balance between technical efficiency and the desired aspects of the remains brought to light. This will require strong collaboration between the archaeologists and the conservators involved, in

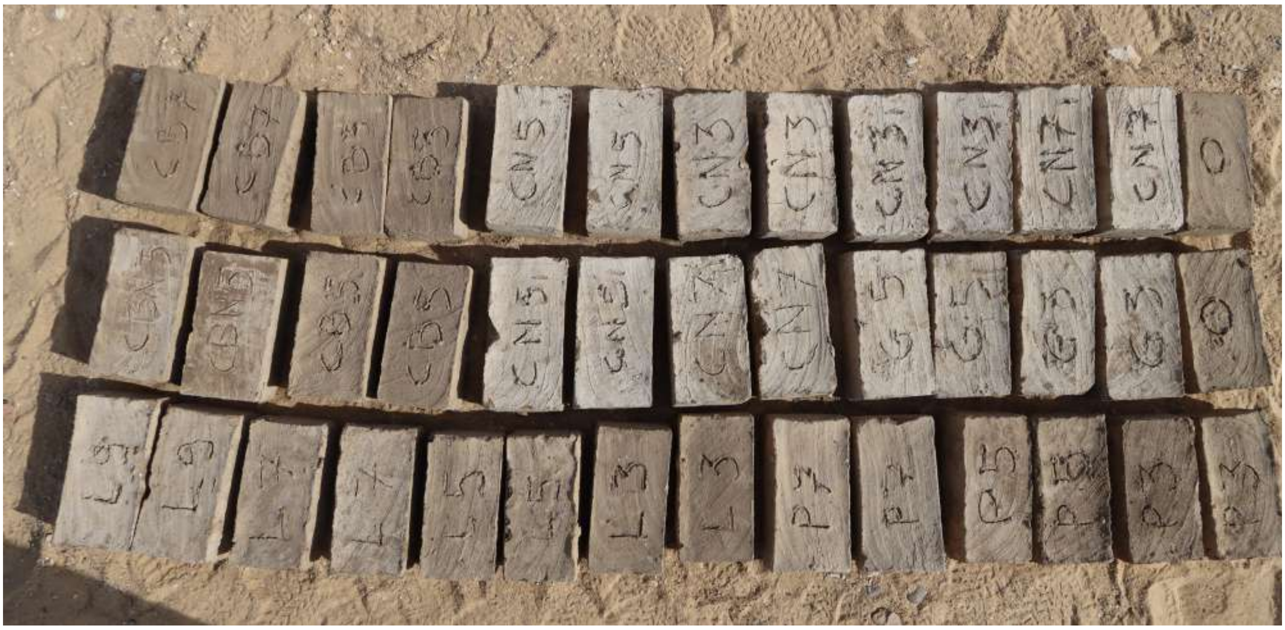

Figure 11: Samples of bricks prepared using a variety of stabilizers and dosages.
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order to also meet the requirements of authenticity and proper documentation and identification of both original and new fabrics used for the protective layers.

The collaboration at Pepy I acknowledges the need to identify temporary solutions that are inexpensive and quick to install to ensure the protection of recently exposed vestiges between two successive seasons, allowing for their proper study before a longer-term, in-depth conservation plan can be implemented.

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BARAKA: REVITALIZATION OF SUDAN'S OLDEST PRESERVED MOSQUE AT OLD DONGOLA. CONSERVATION OF THE WALL PAINTINGS, PROJECT ASSUMPTIONS AND PRELIMINARY TEST RESULTS

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SUMMARY

This paper presents preliminary results of a research on the conservation of the wall paintings in the mosque at Old Dongola, Sudan. From the 6th to the 14th century Old Dongola was the capital of the Christian kingdom of Makuria; later on, from the 16th century it developed as a regional and political centre associated with Islamic culture. The above is reflected in the history of the described building, which dates back to the 9th century, built as a church or a throne hall. In 1317, the building has been converted into a mosque and remained as such until 1969, when the building was closed due to a collapse risk.

The article introduces the subject of the paintings discovered in the mosque and located in the Central Hall and the staircase. The latter are covered with many layers of plaster, therefore extensive research is required. The paper presents previous and current conservation works with a specific focus on the assumptions, preliminary studies and stratigraphic investigation of wall paintings developed under *a* project financed by the Aliph Foundation*: Baraka, Revitalization of the oldest preserved Sudanese mosque at Old Dongola*.

INTRODUCTION

As a matter of principle, archaeological site conservation involves protection of structures that have been hidden from the human eye for centuries. These objects are often devoid of secondary layers and have remained unchanged for hundreds of years. The case of the mosque at Old Dongola is different. Since the 9th century, this building has performed several functions and therefore has undergone numerous renovations, maintenance works and modifications regarding the interior design. The afore-mentioned creates an additional challenge for conservators, not only as it comes to protecting the structure itself, but also understanding its complex stratigraphy. The problem of diagnosis, documentation and monitoring of the structure allows creating a complete conservation project. Thanks to the works that have been undertaken *in situ*, which comprised the analysis of the stratigraphy and the history of the building, it was possible to elaborate a project making it possible to show all the important historical periods of the building. The foregoing will allow illustrating the cultural heritage of this region while conservation principles of reversibility and minimum intervention will be applied to all the executed works in a manner allowing more investigations to be done in the future.

The main part of the building was in use since the 9th century and served as the Throne Hall of the Nubian kings or a church. Later on, during the 14th century, the building was converted into a mosque. Thus, the building was in use for over a millennium, and as such has undergone several renovations, repairs and modifications. Currently, only a small part of the building is open to the public. Restoration works have to be carried out so the monument may serve as a regional landmark. That also requires the indication of the existing pathologies since main causes of damage are, among others: variable weather conditions and heavy rainfall, bats inhabiting its interior and termite attacks. All these factors combined with the complexity of the multilayer paintings raise the need for a holistic conservation plan for the building that is not just a temporary repair but an overall restoration plan. Hence, the *Baraka project* has been elaborated as a space of cooperation between specialists representing complementary disciplines: constructors, conservators, architects, biologists and archaeologists. One of its assumptions is an extensive plan of conservation of the wall paintings.

1. OLD DONGOLA – KINGDOM OF WALL PAINTINGS

The archaeological site of Old Dongola is located between the 3rd and 4th cataracts of the Nile. The city, located by the eastern side of the river, was founded in the late 5th century and became the most important urban centre during the medieval kingdom of Makuria[1]. Archaeological excavations on site were commenced in 1964 by an expedition of the Polish Centre of Mediterranean Archaeology, University of Warsaw[2], which has been conducting fieldwork over there to the present day. The archaeological site covers an area of about three-square kilometres and includes a citadel, the Monastery of St. Anthony (Monastery of the Holy Trinity)[3] on Kom H and a dozen of churches.

The largest concentration of wall paintings may be found in the monastery located about 1.5 km to the northeast of the citadel. The sacral complexes are so-called annexes. The NW Annex distinguishes several chronological phases with visible reconstructions and additions.[4] This includes duplicated spaces of naos, sanctuaries and pastophorias.[5] The walls are decorated with compositions from the Old and New Testaments. The paintings represent both the classical themes of Eastern Christian art and a unique fusion of Byzantine influences, Islamic and local traditions. In addition to motifs depicting the Mother of God, Jesus, archangels or apostles, there are also depictions of Nubian dignitaries under the protection of saints or archangels.[6]

In the monastery there are also paintings transferred from the Monastic Church[7] and the NB2 church discovered in 2018.[8] Inside the citadel, there are paintings in the churches B.V and B.III, and also in the mosque. In the period 2020-2023, paintings were also discovered in the apse of the Church of Jesus and U292.[9] Currently, they are secured and covered with sand.

Conservation works on the archaeological site of Old Dongola began with archaeological research; one of the first activities was the conservation of the paintings found in the residential houses. Subsequent activities focused on the area of the monastery (KOM H) and concerned polychrome paintings discovered mainly in NW Annex and SW Annex. At the same time, wall paintings from the Monastery Church were transferred. Along with the progress of archaeological investigations and new projects, conservation works began in the Church of Archangel Raphael, at B.III and in the Mosque.[10] In 2018, cooperation with the Academy of Fine Arts in Warsaw was established. After *in situ* inspection by the staff of the Department of Conservation and Restoration of Works of Art, the *Project for conservation work on the wall paintings in Old Dongola, Sudan*[11] was elaborated. In addition, the scope of documentation has been extended with the creation of the *Object Charts and Conservation Documentation*. Conservators complete diagrams with damage maps and conservation intervention maps every year. Today, the restoration work is focused on protection of the paintings in the B.V – Archangel Raphael Church located on the citadel, in NB2, located on the territory of the monastery, and in the Mosque.

2. THE MOSQUE BUILDING[12]

The Mosque building is located on a rocky outcrop, between the citadel and the Muslim necropolis, 12 meters above ground (dimensions of rectangular plan 28 x 18 m) across three main levels, including a 6.5-meter ground floor, 3-meter first floor and a staircase. There is an apse lying on the eastern wall axis. The first floor has no direct access to other rooms. The building had probably three entrances: two from the north and one from the south.[13] The ground floor consists of two long corridors along east and west walls and five long narrow rooms, aligned on the north-south axis. Originally, the ground floor

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1. Godlewski 2013, p. 7.
2. Michałowski 1966, pp. 289-299; Godlewski 2013, p. 14.
3. Both names used in the literature, see: Jakobielski 2008, p. 271; Godlewski 2013, p. 79.
4. Jakobielski 2001.
5. Zielińska 2009, pp. 121-125.
6. About wall paintings from the monastery in Kom H: Martens-Czarnecka 2011.
7. Zielińska 2019, p. 91.
8. Church unpublished as a whole, the discovery of the church is mentioned in articles: Godlewski 2019, p. 479; Łajtar, Van Gerven Oei 2021, p. 531.
9. Unpublished discoveries, promotional materials: https://pcma.uw.edu.pl/en/2023/04/05/new-discoveries-in-old-dongola-protection-for-tungul-new-unique-wall-paintings-discovered-in-old-dongola-sudan/?fbclid=IwAR1ioJGm__WYgRMn1sB2LzT_Ae64n3NmO-QlFgxEcTm3s6lU3p-lbydlzzYo, https://pcma.uw.edu.pl/en/2021/05/26/cathedral-of-dongola-new-discoveries-in-sudan/
10. Zielińska 2019, pp. 91-92.
11. Baran, Chmielewski, Sawicki 2018.
12. More information about the building construction and its history: Fushija, Siedahmed, "Testimonies of cooperative care: Socioeconomic system of the maintenance of the oldest mosque in Sudan" in this Volume as well: Godlewski, Medeksza 1987; Godlewski 2015, Obłuski et al. 2013.
13. Godlewski, Medeksza 1987, pp. 187-189.

ceilings were constructed as vaults with a cross section; the roof of the upper floor is composed of wooden beams supporting palm-rib mats coated with mud plaster (*muna*). The stairs from the ground floor to the first floor are vaulted since the stairs to the roof did not survive in their original condition. The first floor features a Central Hall surrounded by ambulatories corridors.

Allegedly, the building dates back at least to the 9th century and falls under the Makurian period. Most probably, it served as a church or the throne hall of the Makurian kings during the Christian era. Unique mural paintings from the 9th to 12th centuries[14] are preserved in the staircase and Central Hall. By the end of the 13th century destructions have occurred; especially within the area of the south wall due to the wars with the Mamluks. Repairs after this damage influenced significantly the shape of the building, which was reinforced at this time with a buttress retaining wall. Parts of the exterior walls of the first floor were rebuilt as well, limiting the original open porticoes. The building was also fitted with its flat roof, which exists until now.[15] Later on, in 1317, the building was converted into a mosque, which was used until modern times, short interruptions included.

2.1. WALL PAINTINGS CHARACTERISTICS

The paintings in the building in question are located in the staircase and in the Central Hall.[16] The iconographic program in the Central Hall is available only after the survey realised before implementation of the conservation works. In this room, as well as in the staircase, there were numerous traces of repairs and secondary plasters on which one or more layers of paintings had been applied.[17] Some of the paintings are repainted respecting the original condition; others show various iconographic themes in one place, with different chronology. Iconographic themes were studied by Ph.D. [dr. hab.] Dobrochna Zielińska[18]. Nativity scene on the northern part of the eastern wall is considered to be the most visible. There are two layers of paintings that repeat the same motif. On a western part of the south wall, several different scenes may be noted: Flight to Egypt[19] (repainted twice), Transfiguration and Holy Trinity with a figure of the king that was added subsequently.[20] In the western part of the northern wall, there are three phases of decoration: *crux gemmata*, added to the cross, Twenty-Four Elders and figures of a bishop and a king (Fig. 1).[21]

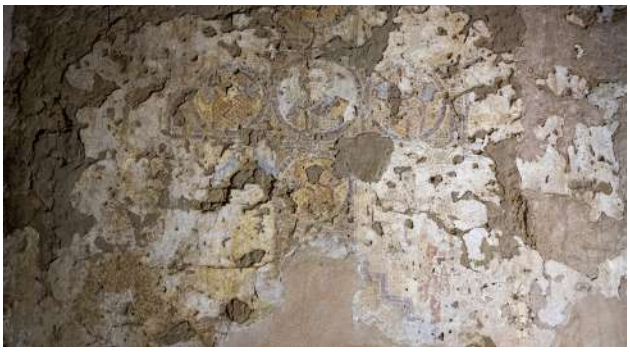

Figure 1: Crux gemmata, northern wall of the Central Hall.

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The paintings of the staircase were noticed during previous archaeological campaigns and are visible under the layers of plaster peeling away. Since two stratigraphic windows were made figures of holy warriors were revealed: on the south wall there a standing figure holding a spear and mezzanine above a holy warrior on a horse[22] may be seen. In addition, stratigraphic window made in 2023 on the eastern wall of the staircase revealed fragments of two figures of archangels.

2.2. TECHNOLOGY[23] OF WALL PAINTINGS

Research on the technology of Nubian painting that started on a larger scale during the Nubian campaign[24] is constantly providing new information about the binders, pigments and mortars sed. Thanks to the latest technologies one may get more precise results according to which there were different technologies applied depending on the surface and location.[25] Wall paintings found in Old Dongola present a broad chronological range. The variety of technologies starts with a distinction between churches with paintings for which lime and clay-based plasters and whitewashes were applied.[26] According to analysis of Nubian paintings the most common components are: gypsum, calcium carbonate, carbon black, yellow and red iron oxides, hematite, massicot, litharge, lapis lazuli, Egyptian blue, green earth and atacamite.[27] As recent research proves, an egg-based binder was used in Nubian wall paintings as well.[28]

In the mosque, the paintings have been applied on a wall made of mud bricks (35 x 18 x 8 cm) and fired clay bricks (32 x 16 x 7 cm)[29], which were used only for the interior walls of the stairwell (F30, F31, F32, F33, see: Fig. 6.) The paintings are executed on clay plasters, with local lime wash[30]. According to the research carried out in the mosque, the pigments used in the Central Hall are as follows: natural iron oxide red, lapis lazuli, and silicate or phosphate ions as a green pigment. Proteins, in addition to lime, namely ovalbumin and lysozyme (egg white)[31] were found in binders. More detailed research within this area is to be continued aimed at getting to know better and reflecting on conservation measures applied.[32]

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[14] There are different chronological phases of the painting decoration. Perhaps more accurate dating of individual layers will be possible once the C14 research is commissioned under the Baraka project.

[15] Obłuski *et al.* 2013, pp. 248-252.

[16] Small fragments with the paint layer were found in 2023 on the ground floor; however, due to the degree of degradation of the plasters and extremely limited fragment, it is difficult to assess their extent and form.

[17] Calaforra-Rzepka *et al.* 2015, p. 37.

[18] Zielińska 2015, pp. 25-36.

[19] Showing a palm tree bowing before Jesus Christ based on Pseudo-Matthew, chapter 20.

[20] Zielińska 2015, pp.30-31.

[21] Innemée, Zielińska 2018.

[22] Obłuski *et al.* p. 259.

[23] See more about construction technology: Terlikowski et al. *this Volume*

[24] Zielińska 2019, p. 1.

[25] The latest and most comprehensive study conducted so far: Zielińska 2019.

[26] Zielińska 2019, p. 67.

[27] Ibidem, p. 74.

[28] Galluzi *et al.* 2019, p. 54.

[29] Godlewski 2013, p. 43.

3. PREVIOUS CONSERVATION, RESTORATION AND RECONSTRUCTION WORKS

The building appearance suggests that it has undergone multiple reconstructions; most of them unrecorded in reference literature. As for renovations and repairs in modern times, according to the sources, in the late 18th century, the mosque was "restored" according to local traditions. The next major restoration was carried out at the beginning of the 20th century. Subsequent repairs focused mainly on the roof sheathing.[33] Since the 1970s, the site was acknowledged by the Polish archaeological campaigns and it became possible for a team from the Polish Centre of Mediterranean Archaeology at the University of Warsaw to prepare documentation and conduct works inside the mosque building. Additionally, repair works on the roof and staircase were carried out between 2015 and 2017.[34] In the period 2009-2012, the paintings in the Central Hall were subject to preventive conservation works[35] within the scope of the planned renovations in the mosque and, more specifically, the need to secure the interior walls. Prior to conservation, the paintings were covered with multiple layers of secondary plaster, with outer layers that were cracked, scratched with inscriptions, and had visible traces of rainwater infiltration. In addition, visible tunnels created by termites, bat droppings and wasp nests were found on the paintings. Photo report and various stratigraphic tests were performed to reveal unique stratigraphies present on each wall. The secondary plaster layers were removed before mechanical cleaning of the walls. Water, alcohol, and ammonium carbonate (1:4 in water) were used for cleaning some of the areas. Then, 5% Primal AC 33 was applied locally to reinforce the plasters and their edges. New bands were made using a clay-sand mortar. The paint layer was protected with 2% Paraloid dissolved in toluene.[36] Not only did the works protect the walls during the necessary restoration works on the walls, but also revealed previously unseen paintings, expanding public knowledge of the ancient Nubian iconography.

4. RECENT CONSERVATION WORKS

From January to March 2023, the first conservation works of the BARAKA project took place in the mosque in Old Dongola.[37] The primary objective of the initial conservation was to identify the extent of the painting presence and other historical layers by conducting stratigraphic tests, obtaining samples for further analysis, and dividing workflow and conservation tasks.

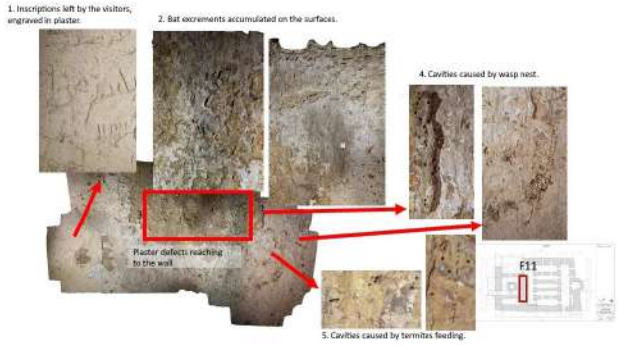
1. Inscriptions left by the visitors, engraved in plaster.
2. Bat excrements accumulated on the surfaces.
4. Cavities caused by wasp nest.
Plaster defects reaching to the wall
F11
5. Cavities caused by termites feeding.

Figure 2: F11 wall. Examples of damages.
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4.1. ASSUMPTIONS OF THE PROJECT/ METHODOLOGY

The project aims at conserving the wall paintings located in the Central Hall and the staircase of the building. The paintings in the Central Hall had been already subject to preliminary conservation treatments, but their state of preservation required additional work. Plasters were debonded and painting layers were covered in dirt. The paintings preserved in the staircase were covered with layers of secondary plaster that made the conservation works time-consuming and complex. The project had foreseen minimal intervention in the painting layers: cleaning, reinforcement of the structure, application of fillers and protective tapes. Such efforts were supposed to preserve the material and structural aspects of the artwork as well as improve the visual perception of the paintings, site history and heritage.

At the first stage of conservation work, the following activities were planned:
- in-depth archival research of the building conservation and reconstruction history;
- 3D scanning of the interior and exterior of the building before and after the conservation works, in order to document the existing condition and the final work effect;
- preliminary photo and descriptive reports of the monument before conservation works,
- in situ studies and documentation, identification of types of damage and its causes;

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[30] Jeżewska, Zadrożna 2015, pp. 43-49.

[31] Ibidem, p. 50.

[32] Samples of mortars, pigments and binders are subject to laboratory tests.

[33] Obłuski *et al.* 2013, p. 252.

[34] Tarczewski 2018, p. 243-254.

[35] Conservation team: by Cristobal Calaforra-Rzepka, Urszula Dąbrowska, Dorota Moryto-Naumiuk Karina Sosnowska, Amal Mohamed Ahmed and Mohammed Sadik (restorers from the Restoration p. 91Department, Sudan National Museum), see: Zielińska 2019, p. 91.

[36] Calaforra-Rzepka *et al.* 2015, pp. 37-42.

[37] The conservation team in 2023: Dawid Szymański, Bogna Skwara, Anna Kwiatkowska, Dominika Siwek, under supervision of prof. K. Chmielewski and Magdalena Skarżyńska.

- tests of conservation materials to be applied for reinforcement of the masonry and plasters;
- preparation of damage maps;
- sampling, laboratory tests.

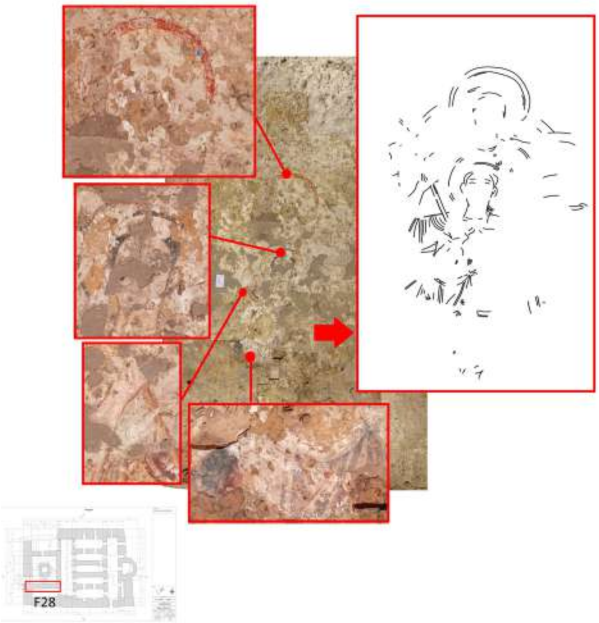

Figure 3: F28 wall. Result of the stratigraphic test.
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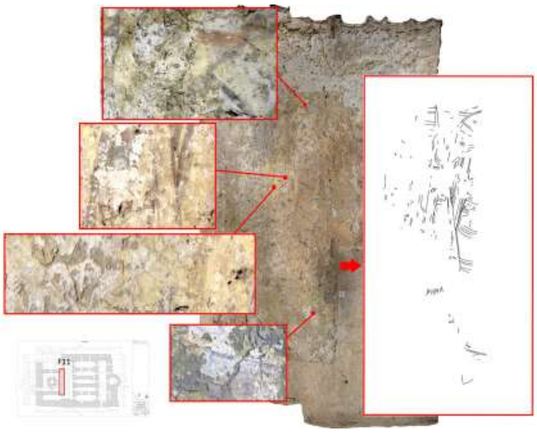

Figure 4: F11 wall. Result of the stratigraphic test.
© PCMA, University of Warsaw, A. Chlebowski, M. Skarżyńska

Sampling was supposed to determine the characteristics of the layered plaster structure, identify binders and the type of wood that structural elements are made of. Laboratory tests analysing variety of the plaster layers and identifying pigments were assumed be performed using the SEM-EDS, gas and liquid chromatography methods. Microscopic observations would also be carried out under a stereoscopic microscope and a biological microscope with transmitted light, polarized light and a dark field. Additionally, C14 tests were planned.

4.2. STATE OF PRESERVATION AND CAUSES OF DAMAGES

The condition of the building was assessed as poor or even critical. Since adobe had been used as a traditional construction material it was prone to erosion and losing its internal consistency with relative humidity level. Thus, the key factors responsible for the deterioration of the mosque plasters and paint layers were inadequate roofing and lack of protection against previous water infiltration.

Sudan has a climate with large temperature variations, reaching over 30 degrees between day and night. During the rainy season, structures may be subject to adverse weather conditions, resulting in possible destruction while the sudden increase of humidity level leads to increased insect activity, especially termites that attack organic components of walls and plasters.

Furthermore, an insufficient window protection and open-door frames invite bats to settle in the rooms. This detrimental effect occurs not only due to the fact that their excrement seeps into the plaster, but also because of the physical damage caused by them.

Apart from dirt on the surface, significant detachment of the plaster, cracks, rainwater infiltration damages, cavities caused by wasp nests, termite feeding may be noticed locally. Bat excrement is penetrating the plasters and is being accumulated on the surfaces along the vault, affecting their colours (an example of scope of damages, see: Fig. 2, Fig. 5).

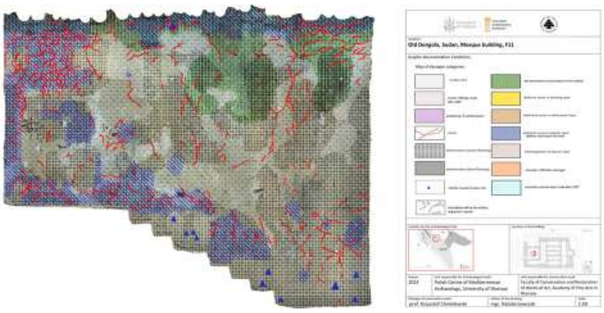

Figure 5: F11 wall. Map of damage categories.
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The paintings present poor condition. The original compositions have been painted over and plastered several times. The paint layer is preserved in some areas; however, it duplicates damages of the plaster. There are also some significant and visible losses of the paint layer, detachments, along with whitewash. A number of scratches, scuffs and chipping of the paint layer may be stated. On F33 wall the paintings were intentionally insulated with gauze and covered with plaster during previous restoration to protect them against further damage.

In such conditions, it is not surprising that the walls were subject to multiple restorations and are coated with several layers of additional plaster. Certain areas are devastated with inscriptions engraved by visitors, which may be considered as important historical evidence of the existence of the mosque and in some cases should be conserved.

Modern plaster layers containing Portland cement must be removed as they do not comply with historic buildings. The high shrinkage during cement curing and lack of permeability cause delamination and irreversible damage to the historical material.

5. PREPARING FOR FUTURE CONSERVATION WORK

Before commencement of conservation works, photo reports of the interior walls, as well as 3D scans of the entire building were made. It enabled elaboration of the damage maps of the walls on the staircase and the Central Hall. An in-depth analysis of both detached plaster and damages of walls was performed in situ. The types and scope of damage and their causes were analysed. Tests were conducted in order to examine the effectiveness of agents aimed at strengthening mud mortar: KSE 100, KSE 300 (Remmers), nanolime (Nanorestore CTS) and Syton X30 (Kremer). The best results were obtained when Syton X30 in a 1:3 ratio with water was applied. A methodology for removing wasp nests (mechanically) has also been developed. Elimination of discoloration of plaster from bat droppings creates difficulties, but is partially possible by using ammonium carbonate compresses.

Such solutions will be used to remove the damages already present; however, it is important to determine a system mitigating such risks in relation to the paintings in the future. This aspect requires cooperation between specialists. As it comes to restoration, apart from reinforcement of the structure and restoration of the roof ensuring water-resistance of the building, it will be necessary to replace the windows and to provide nets inside so bats cannot fly into the building.

The cooperation with the chiropterologists participating in the project was of considerable importance. Their work consisted in identifying bat species and determining their number in each room, as well as collecting materials for further analysis. Nocturnal recording of echolocation signals of flying bats with detectors was carried out. Samples of guano were collected from specific places, from which it will be possible to determine the species of insects and other invertebrates that constitute the bats food together with DNA analysis. That will lead to a better understanding of their environment and their role in local ecosystems[38]. The next step consists in developing a system for relocating bats to other places.

During conservation works in this season, 53 samples of plaster, pigment, brick, wood, and biological efflorescence were collected. The samples were analysed and a report entitled: "Analysis of Plaster Samples and Paint Layers from a Mosque at the Old Dongola Archaeological Site, Sudan" [39] was prepared. In addition, 37 stratigraphic tests were made. Each of the walls of the staircase has been checked in view of identification of stratigraphic layers, reconstructions and modifications made in the past. Stratigraphic windows were extended to reveal the lowermost plaster layers.

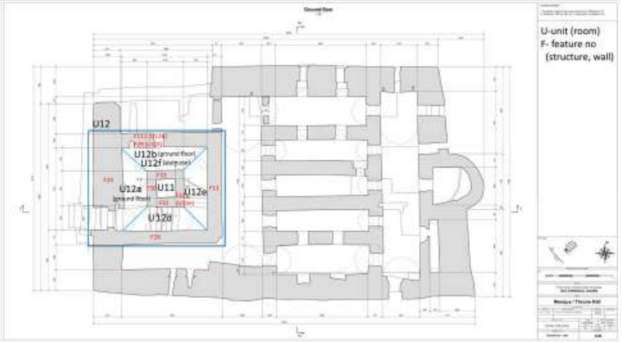

Figure 6: Map of the mosque with unit and feature numbers on the staircase.
© PCMA, University of Warsaw, R. Tarczewski

As part of the documentation, an additional catalogue of stratigraphic windows was created, including taking pictures of each stratigraphic layer, with numbering and determining characteristics of each layer as well as identifying the location of the stratigraphic tests within a broader context. Pursuant to conclusions each layer is connected to analogous plaster on another wall of the building. The plaster layers were gradually removed, with each stage properly documented, in order to prepare stratigraphic windows mentioned before. Secondary plasters were removed mechanically using a scalpel. The most sensitive and prone to chipping parts were reattached using Primal AC33. Then, the plasters were strengthened locally and reinforced with Primal WS24. Stratigraphic windows show from 3 to 12 stratigraphic layers from different periods (Fig. 7). This helped to determine the area of presence of wall paintings.

F32 wall, coated with cement plaster, presented original mud plaster with abundant filler in the form of straw, as well as *jir* whitewash. This layer was directly applied on the fired clay brick. Painting decorations were found after stratigraphic testing on F28 and F11 walls. They revealed up to 13 stratigraphic layers, including some of them with remains of paintings from different periods.

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[38] https://naukawpolsce.pl/aktualnosci/news%2C95250%2Cnaukowcy-z-upp-zbadali-nietoperze-zyjace-na-stanowisku-archeologicznym-w

[39] The results of the lab tests will be the subject matter of a separate article. Orginal title: „"ANALIZA PRÓBEK TYNKÓW ORAZ WARSTW MALARSKICH Z MECZETU NA TERENIE STAREJ DONGOLI, SUDAN" E. Jeżewska, J. Kurkowska, A. Puchta, A. Wesołowska, B. Witkowski, Warsaw 2023.

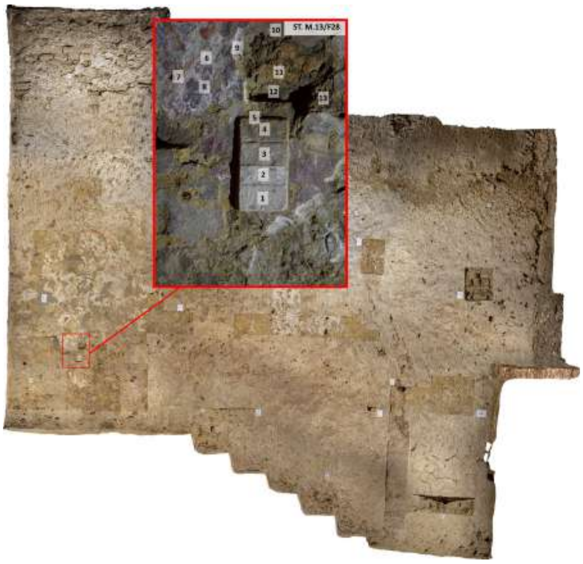

Figure 7: Stratigraphic test ST.M.13/F28.
© PCMA, University of Warsaw, A. Chlebowski, A. Kwiatkowska, M. Skarżyńska

On the walls, three layers of paint from different periods containing depictions of religious figures were discovered. One layer on F28 wall portrays a holy warrior with a spear, repainted from an earlier layer, above which there are nimbuses belonging to an even earlier stratigraphic layer (Fig. 3). F11 wall contains fragments of the figure of an archangel, with a fragment of another archangel's wing visible on the right side. An older colour layer may also be observed under the layer displaying the archangel (Fig. 4).

On F31wall, yellow mud plaster with grey *jir* whitewash may be noticed as well as prayers in Arabic (Fig. 8). Yellow plaster, is considered to be the first from the period when the building was converted into a mosque. Such assumptions are identical to the results of stratigraphic research conducted in the Central Hall[40]. It was possible to remove about 1/3 of the secondary plaster under which the paintings or inscriptions are located, and 2 walls have been designated and will remain in their current form.

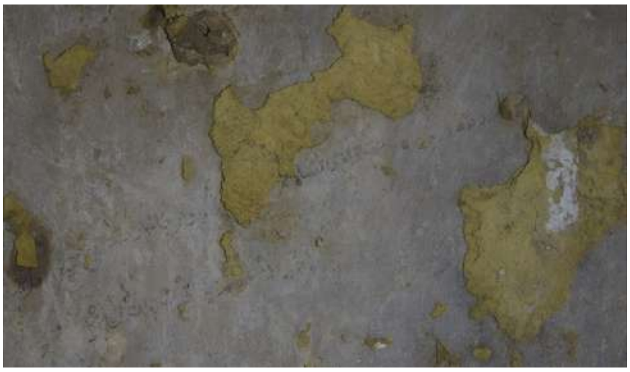

Figure 8: Arabic inscription on the F31 wall.
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CONCLUSIONS

The stratigraphic investigation revealed historical layers previously hidden under the secondary plaster. Several internal conservation committees were conducted during the works. At that time, the final conservation project was discussed. The aim of the Baraka project is not just implementing conservation works but showing the history of this place with respect to each of its historical layers.

Therefore, after consultations, it was decided that the plasters on F30 and F29 walls will remain in their current form due to the inscriptions present on them and the specific forms of writings that are relevant to the grafitto mosque. F31 wall, following stratigraphic research, did not reveal preserved colour layers, However, the ink inscriptions on the plaster invoking Allah are still visible, making them extremely valuable for the history of the building. This wall will be cleaned up to a layer with Arabic inscriptions.

Most remains of colour layers were discovered on F11 and F28 walls, which will be cleaned of secondary layers to make the paintings clearly visible. Each of the layers will be removed gradually. It may be determined whether there are no further inscriptions on the plaster, probably from the first mosque. Then both layers will be preserved.

The holistic plan for the building's preservation involves collaboration between specialists from different fields. Through consultations with constructors, chiropterologists and the possibility of cooperation with the local community, it was possible to elaborate a comprehensive project that protects the building itself as a cultural asset. The plan to leave part of the walls with modern signatures and prayers is a result of discussions with ethnographic specialists and proves the continuation of the building's history. Thanks to this, the staircase will be a representation of all the periods and histories that this building may tell.

Thanks to the modern technologies like 3D scanning and orthophotogrammetry, now we may document every stage of a building project, including modification of the building space during maintenance works and once work is completed. Thus, an additional objective of the project is to show the entire development of the historic building.

The preservation of monuments protects memory and is an important carrier of cultural identity. That is why the main goal of Baraka project is to cooperate with the local community and consult every stage of the conservation work that is carried out with the NCAM. An agreement regarding the conservation design of the building's interior and visual presentation of the most important historical changes has been prepared.

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[40] Zielińska 2015, p. 25.

ACKNOWLEDGMENTS

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MAINTENANCE AND RESTORATION OF MUD AND MUD-BRICK BUILDINGS: KHANDAQ TOWN AS A CASE STUDY

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University of Khartoum

SUMMARY

The town and river port of Khandaq in Sudan was developed from the 6th century up to the later 20th century during a culturally rich period for which much documentation remains. Khandaq was a major trading town from western Sudan to the coast and north-south along the river Nile. It was established during the Christian period, and later occupied by Muslims as part of an Islamic kingdom into the 19th century and became the center of a governorate in the Condominium period and revived as a trading center until the late 20th century. This paper presents a case study of multi–story buildings at the town showing them as examples of successive functions. One location developed from Christian buildings and material culture to an Islamic-period castle. Architectural, documentary, and photographic evidence will be used to follow the development of this type of building. Connections in architecture of multi-story buildings will be examined, both those of Christian and later Islamic architecture which spread along the Nile Valley, through trading links Khandaq had with western Sudan and the Mediterranean. The historical evidence can be used for a greater understanding of how local builders were influenced by local traditions and from other regions, particularly in their understanding of multi-story buildings. This understanding affected the methods and materials currently being used in the restoration of mud and mud-brick buildings in the town. A case study will examine how the traditional uses of materials can be used in the conservation to produce results compatible with the historical and cultural evolution of the town. The project was made possible through the support of the Qatar Sudan Archaeological Project.

INTRODUCTION

Mud brick systems were valued throughout history for beneficial thermal properties, providing thermal mass and insulation qualities beneficial in both summer and winter from the oldest surviving examples in ancient Mesopotamia and Turkey[1] In the central Sudan mud brick construction is often referred to as ‘adobe’ which is based on an Arabic and Berber word eventually brought by Spaniards to the Americas, where is often used when referring to mud brick. As in most of the world where it is used, mud brick is made by combining earth with water and other materials, based on local traditions, mixed, placed in a mold and dried in the sun. Consequently, the bricks have minimal environmental impact.[2]

Mud brick architecture reflects the culture and customs of the Sudan as it paints a clear picture of how the people lived and dealt with their physical environment, political surroundings, economic aspirations, beliefs, and their interaction with others throughout their history. The material is easily adapted for a multitude of uses, often resulting in creative designs for solving various problems. The Sudan’s population used their traditional knowledge for economic advancement, military safety, social stability, population cohesion, and the spiritual and physical security of the region. Another advantage of mud brick is that can be recycled and returned to be used for agricultural purposes. The traditional uses can also be adapted to address modern building and population needs with the encouragement of proper scientific research and studies.[3]

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[1] Oates 1990, 388

[2] Bianco 2002.

This important heritage is now under threat, despite its economic, social, and environmental value. Modern concrete construction has spread throughout all regions and has threatened the natural building materials with destruction. An understanding of traditional mud brick architecture is needed to safeguard this important heritage, safeguarding memory, preserving the environment, ensuring self-sufficiency, and combating poverty and social inequalities.[4] The better understanding will benefit the maintenance and restoration Khandaq ancient town buildings.

1. RESEARCH OBJECTIVES

The research aims to investigate the factors influencing the maintenance of mud buildings and identify effective maintenance techniques, by reviewing review existing literature on the maintenance of mud buildings in Khandaq to establish a theoretical framework and to identify knowledge gaps. The objectives of the study are (1) to develop an understanding of the current state of mud building maintenance practices and their effectiveness, and (2) to document different types of mud buildings in Khandaq including their architectural features, construction methods, and current condition through field surveys, the examination of historic records and documentation. The research will explore the historical and cultural context of mud buildings in Sudan in general and Khandaq in specific, including their significance, traditional construction techniques, and their role in local communities. The result of these objectives is to develop a plan for protection and preservation.

1.1 THE METHODOLOGY OF THE RESEARCH AND DATA COLLECTION

The research will be directed by the field director of the Khandaq project and will focus on identifying and interviewing those involved in mud brick maintenance and restoration in local communities. Experts in the field will also be interviewed, to collect their perspectives on mud building maintenance and restoration. This research will identify mud buildings in Khandaq for the study by a comprehensive review of existing literature on mud buildings, traditional construction techniques, and maintenance and restoration practices in Sudan and a comprehensive field study. The selected buildings will be documented through visual inspections, measurements and assessments of their condition, their structural stability and the actual or potential causes of deterioration. This knowledge can provide a deeper understanding of the challenges, opportunities, and best practices related to the maintenance and restoration of mud buildings in Sudan, inform future conservation efforts and contribute to the sustainable preservation of Sudan's rich architectural heritage.

2. MUD BUILDINGS IN SUDAN

Mud is one of the first construction material beside thatched in the different regions of the Sudan except for the dense rainfall areas (using hut buildings) and Sudan has valued mud brick buildings from the early prehistoric, extending back to the Mesolithic, as seen in recent discoveries at el-khiday, the second phase of site 16-D-5, Middle Mesolithic (7th millennium BCE). "Characterized by low mud walls and associated fireplaces."

Mesolithic wall in Jebel Moya. Season 2023: The main dried mud wall. It rests on a dried hard mud base rising 20 cm from the bedrock. The mud wall is direct on this deliberate, man-made base. It is Late Mesolithic 7000 years ago. Later, during the Classic Kerma phase, mud brick architecture reached a high point of development, with the whole capital city built of mud brick. The still upstanding defuffas are the largest early structures still standing in Sudan.

Mud brick building continued into the later periods, such as the Napatan and then into the Meroitic, as seen in the construction of secular buildings such as palaces at Meroe and Wad Ban Naqa. It was further developed during the medieval period, at Soba as well as fired brick, and later during the Islamic period at the capital of the Fung Kingdom at Sennar, where mud and mud brick construction was used. It was used extensively in other significant settlements at this time, as in our case study at the river port of Khandaq.

Traditional ways of building are still in use in different parts of Sudan whether of mud/mud brick or wattle and daub, as the Materials for making mud bricks are readily available in most areas in Sudan, and in Khandaq town (our case study) it is available as the town is adjacent to the river Nile which provides a lot of silt especially in this region. In some cases, it may be sourced directly from the building site. It is noted that during the late period certain changes were introduced into the mud brick building material. Dung and straw were added to the mud during the process of molding the bricks.

In addition to being a deeply rooted ancestral tradition, the use of mud bricks as a building material has acquired particular importance during recent years as, in most cases, it is the only material available to those wishing to have their own homes. Construction costs associated with the manufacture and laying of bricks can be low when work in done by the owner or done through collective collaborative and participatory work called *Nafir* in Sudan.

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[3] Simmons 1996.

[4] Bianco 2002.

The sites which permit the best study of the characteristics of mud brick architecture, because of its fine state of preservation, are the town buildings in the settlement of Khandaq, as mud brick was the logical choice for economic reasons. However, most of the older houses, when reconstruction became feasible, were replaced by new ones built of stone or (fired) brick (Fig. 1).

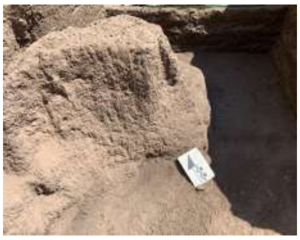
Figure 1a: Mesolithic wall in Jebel Moya.
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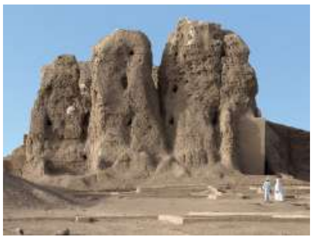
Figure 1b: Kerma: Defuffas building.
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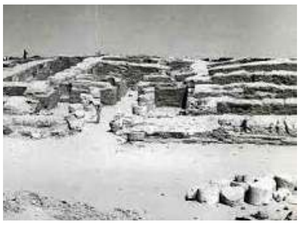
Figure 1c: Meroitic palace at Wad Ben Naqa.
© P. Onderka, 2014:88, Sudan and Nubia, Bulletin Nu.18

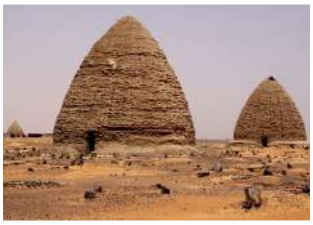
Figure 1d: Dome tomb in Old Dongola.
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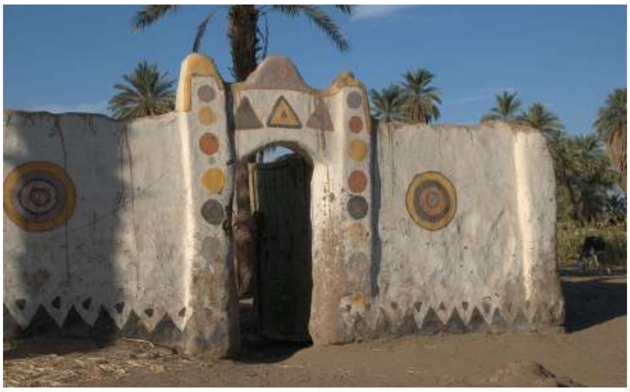
Figure 1e: Mud building house in Nubia, North Sudan.
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3. HISTORICAL BACKGROUND OF KHANDAQ TOWN

Khandaq lies in about 423 km north of Khartoum, it has been a well-known river port town since the early 18th century, though its history goes back to early Christian period, i.e., the 7th century, as testified by the fort and pottery sherds. It was the capital of one of the four petty kingdoms that ruled the area between the 3rd and 4th cataracts of the Nile between approximately the 16th to early 20th century. Khandaq, as a trading town that connected most of the present-day Sudan territories and beyond, was the residence of wealthy merchants, reflected in the size and quality of the houses. Khandaq became the most important settlement in north Sudan with multi story building from mud and mud brick with numerous towns developing around it such as Al Goled, New Dongola, and others.

Khandaq played a major role in the last two centuries as a chief river port that witnessed exchanges of commodities arriving at the port from Egypt and western and southern Sudan. This extended history of Al Khandaq as a river port is attested by several written documents and oral traditions[5]

There are both one-story and two-story houses of mud brick, the latter having many rooms. The two-story houses are constructed of mud, mud brick and occasionally stone and are standing in different states of decay. The majority have been deserted since the early 1970s, when the river trade declined, and the merchants moved to Khartoum, Omdurman, and other main towns of Sudan[6]. They stand today reflecting the glory of the past and the wealth of its inhabitants, mainly the traders.

The fort known as "Qaila Qaila" dominates the town; its south-west tower is visible from both north and south, and its western wall, with the remains of the south-western and interval towers, dominates the area as viewed from the west (Fig. 2).

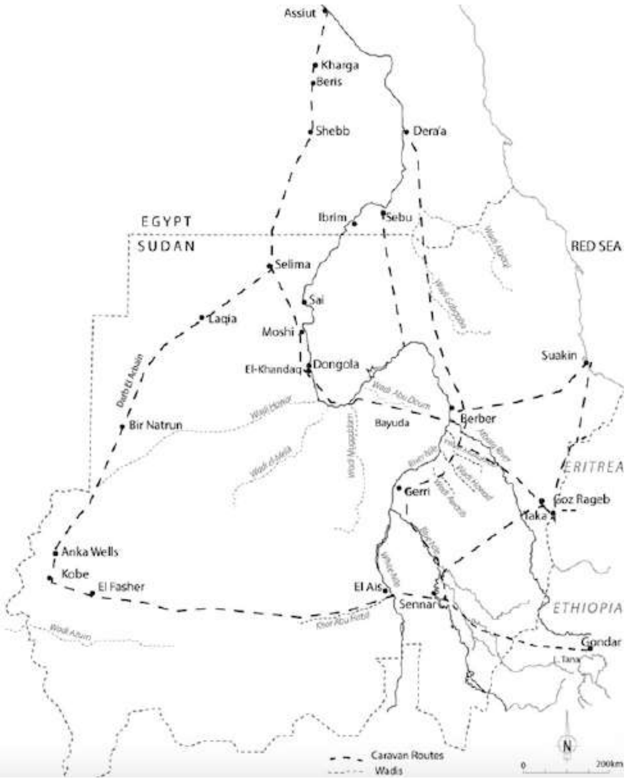

Figure 2: Location of Khandaq in general map of Sudan.
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[5] Adam & Taha 2019, 445.

[6] Soghayroun 2014, 3-5.

Public buildings include the police station (*Mamoriya*), established in 1902, a post office and the customs house. The indigo factory is represented by large granite stones and traces of basins. Other public buildings include the rest-house, which was established in 1905 and officials' residences. There are two mosques, el-Hassanab and el-Khatibiya, which are used intermittently. There are two royal cemeteries and the main town cemetery which is divided spatially among sections of the town i.e., Hassanab, Musiab etc. by natural gullies. Two domed tombs of sheikhs dominate the scene. An important feature of the town is the group vaulted graves that probably date back to the Christian period.

The people of al Khandaq associated themselves with the town (al Khandaq pl., al Khandaqawi sing.), in contrast to the rest of the Sudan, where people are linked to their tribes and are given the tribe's name. This is despite the fact that they are a heterogeneous mixture from inside and outside Sudan as in the case of Suakin and all the port towns in general[7].

The women of el-Khandaq were famous for making objects out of palm leaves and wheat stalks. These ranged from the food covers (*tabaq)* to baskets used as food containers, containers for food carrying, roof hanging devices to keep food fresh, and mats. Women also prepared hearths, or stands, of lime mixed with animal dung, and flooring, also of lime. An ethnographic observation of a female oven maker was carried out as remains of ovens were observed in the deserted houses and are still used by some families elsewhere in the town.

4. THE KHANDAQ REASEARCH PROJECT

4.1 BACKGROUND

Khandaq is important as being the only town surviving with multi-storey mud brick structures. Some of these are well preserved, despite changes in climate caused by the Merowe Dam. However, there is deterioration, and the buildings require restoration and protection for the future; this is the aim of the project.

The project started in 2006 with a general survey of the area and its surroundings, followed in 2009 with a thorough study of the town proper, which revealed the wealth acquired by its inhabitants, mainly the traders and their associates. The study covered, besides the detailed study of the town plan, the interior design of the houses, mosques, cemeteries and other civil buildings erected during the Turkish and then British rule. Thus the town represents examples of architecture with influences from the western desert, from the Nile, and the Nubian and the colonial period. The town witnesses today a sort of nostalgic move from diaspora areas back to Alkhandaq; building of modern houses is under way, making difficult our efforts to preserve the existing heritage[8].

The project has completed restorations for many buildings and houses reflecting the degree of preservation of many of the buildings at Khandaq and the diversity of the architecture. Some of the buildings have arcade porches, courtyards and staircases. One has an external staircase leading up from the courtyard with windows which retain their wooden shutters. The conservation of some of the traditional roofing methods, with woven dome palm fiber matting supported on wooden beams was also a project.

There is also an example of a new building constructed at Khandaq, and the project requested that the style of the building fits in with the older existing buildings and that the colors used should also be consistent with the ones formerly used (Fig. 3).

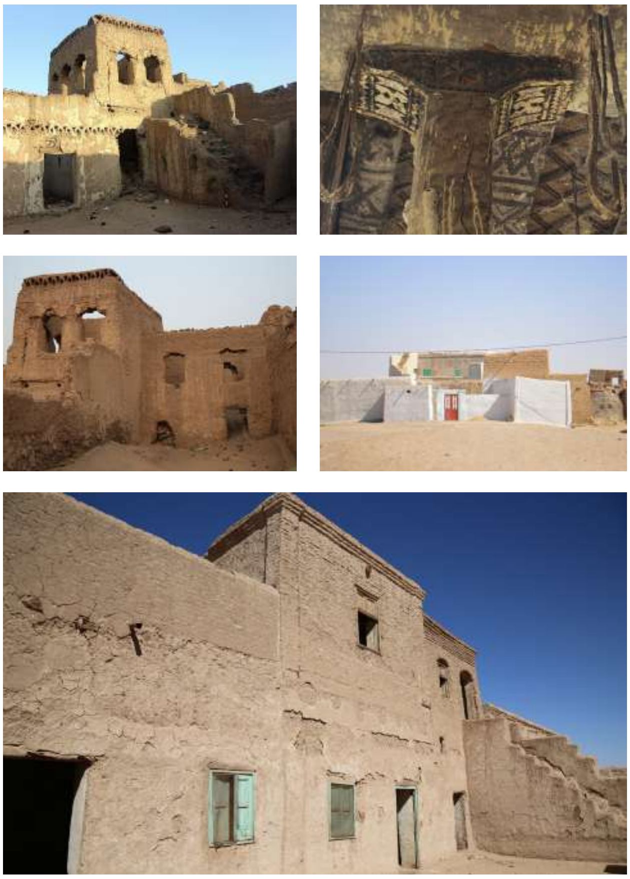

Figure 3: An example of a two-story house with an external staircase and new building
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In general, these studies and conservation of the buildings were made possible by the special project of Qatar Sudan Archaeological Project, but since it was terminated in Sudan, opportunities to carry them further have been drastically reduced after the stopping of the fund (Fig. 4).

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[7] Soghayroun 2014, 6.

[8] Soghayroun 2014, 7-9.

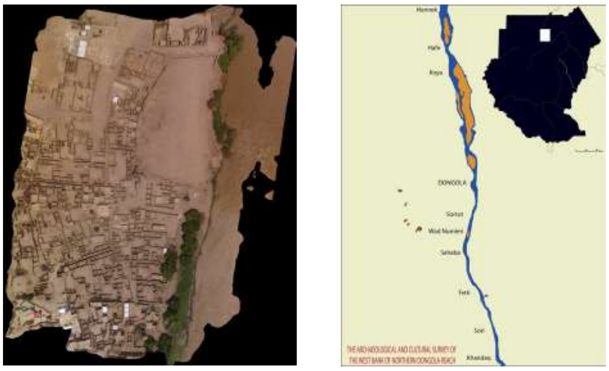
Hannek
Hafir
DONGOLA
Wad Numeiri
Khandaq
THE ARCHAEOLOGICAL AND CULTURAL SURVEY OF
THE WEST BANK OF NORTHERN DONGOLA REACH

Figure 4: Khandaq Town Research Project.
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4.2 DECAY FACTORS IN MUD BUILDINGS

Mud buildings face additional challenges due to rising temperatures associated with climate change. Extreme heat can cause mud to dry and crack, affecting the stability of the structure. Climate change can alter rainfall patterns, leading to more intense and sporadic rainfall events and exacerbate erosion and water damage to mud buildings. Increasing awareness of the impacts of climate change and promoting resilient building practices can help communities prepare for and adapt to changing conditions. This might involve community workshops, educational programs, and collaboration with experts in architecture and climate science. The impact of climate change on mud buildings in Khandaq town and other parts of North Sudan is complex and multifaceted. It requires a holistic approach that considers both the immediate and long-term effects of changing climatic conditions on traditional construction practices. Adaptation strategies, community involvement, and sustainable building practices are essential components in addressing the challenges posed by climate change in the context of mud buildings in the region.

To devise an appropriate approach to the restoration of mud-brick historical monuments of Khandaq, it was first necessary to determine what factors had contributed to their deterioration and in some cases had resulted in their destruction. The following factors were considered:

1. The effects of rain

2. Temperature changes.

3. The condensation of moisture on the surface of the mudbricks (along the river Nile, relative humidity runs from 75 to 100 per cent).

4. Wind erosion accentuated by the abundance of sand along the river Nile

5. The destructive effects produced by man, birds, and insects).

The climate in the north of Sudan is very hot as Sudan experiences mean annual temperatures between 26°C and 32°C, with summer temperatures in the north often exceeding 43°C. The rainfall in Sudan is unreliable and erratic, with great variation experienced between northern and other regions. This is felt in a country as vulnerable as Sudan which has, over the past decades, experienced increasing number of droughts, high rainfall variability, depletion of water sources, and desertification of millions of spaces. The climate in northern Sudan (where Khandaq town is located) has changed considerably after the establishment of the Merwe Dam, The Territory has experienced significant changes in temperature, humidity, so, the effect of Merowe Dam on the local climate was very high and fast. The climatic factors affected by Merowe Dam are (temperature, rainfall, sunshine, moisture, and wind), and heavy rainfall. Heavy rainfall can lead to numerous problems such as flooding resulting in risk to human life, damage to buildings and infrastructure, and loss of crops and livestock.

4.3 OBJECTIVES

The overall aim of the restoration project being undertaken in Khandaq historic town, funded by Qatar Sudan Project since 2013, was the restoration and reconditioning of the historic monuments in the town. The local contribution consisted of providing personnel specializing in restoration and treatment methods to prevent the deterioration of the buildings. The project was provided with suitable equipment to carry out the additional tasks involved in the operations, and funds were earmarked for the training of local personnel by experts in how to deal with the buildings discovered recently during excavations. The project began restoration work in the second season of 2014.

Among its objectives were to establish guidelines for the restoration and reconditioning of the historic monuments, and the building features discovered during excavations, according to priorities established by the by the project director in the overall project plan. Another objective was to complete the restoration, consolidation and reconditioning of the existing historic monuments in the area, especially the general buildings, based on budgets and proper technology required for the different types of buildings. The guidelines address maintenance and site planning.

In this regard, one of the best models established by the project is the museum of heritage.

A multi-story building was donated to the project to eventually serve as a community museum. The conservation of the building and the façade was undertaken by the Project with the initial restoration completed in 2015. The work utilized local materials for the roof and in plastering all the walls. The conservation and restoration also included the house of the officer (Mamur), the house for the telegraphist, and the conservation of an old mosque discovered during clearance in season 2015. The outline of the mosque was restored using traditional methods, including hand-made mud bricks (Fig. 5).

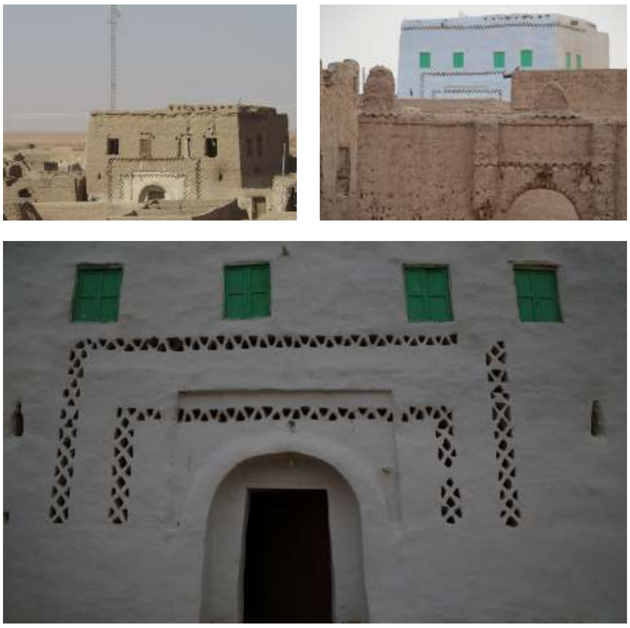

Figure 5: The Heritage Museum before and after restoration.
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4.4 MAINTENANCE

Mud buildings require regular maintenance to prevent decay. Cracks and erosion should be repaired promptly to avoid further damage. In many cases, the lack of resources or awareness about proper maintenance practices can contribute to the decay of mud structures. Termites and other pests can pose a significant threat to mud buildings as well. These insects can weaken the structure by feeding on the mud, leading to structural instability over time.

It was important to determine the maintenance needs of mud buildings in conjunction with local experts, local professionals, and authorities familiar with the area, especially in response to seasonal changes in Khandaq after the formation of the Merwe dam. Maintenance needs must also consider the cultural or historical significance of the mud buildings in the area to respect and preserve the architectural traditions. When repairing traditional buildings in Khandaq town, it is important to follow practices that preserve their cultural and historical significance while addressing structural issues.

Here are some general repair practices that can help maintain the traditional aesthetics and integrity of the buildings :

1. Documentation and assessment : Before starting any repair work, it is crucial to document the existing condition of the building and conduct a thorough assessment. This includes identifying areas of damage, decay, or structural instability. It is also important to understand the original construction techniques and materials used in order to ensure authenticity during repairs.

2. Preservation of original materials : Whenever possible, prioritize the preservation and reuse of original materials. Traditional buildings often incorporate locally sourced materials and craftsmanship that contribute to their unique character. Salvaging and repairing original elements can help maintain the building's historical value.

3. Traditional construction techniques : Employ traditional construction techniques, materials and methods originally used in the area. This may involve reinforcing weak foundations, stabilizing walls, conserving or restoring decorative elements, ornamental carvings, and traditional paint colors using lime mortars, traditional plasters and masonry materials based on regional architectural styles. It can also involve respecting local traditions and materials of timber construction. It is important to consult with structural engineers and preservation experts (local builders from the region) to ensure that the repairs are carried out without compromising the building's historic integrity.

4.5 SITE PLAN CONSIDERATIONS

Identify the natural elements that may impact the structures such as building placement, topography, and natural features. Accessing and planning for proper site drainage is important. It is also important to plan for entrance and egress with roads and pathways and entrances both during the restoration project and for the efficient use of the area and the buildings after the project has been completed. The plan should designate areas for different functions, such as residential, community, police, and tourist offices in addition to planning for utilities such as water sewage, and power.

It is important to access the overall site conditions with the condition of the site structures. Comparing the actual conditions on the site such as the natural and existing grade with the existence and type of foundations, and footings for signs of settlement.

4.6 PREPARING THE MATERIAL FOR RESTORATION

The method of making the mud bricks:

Making the mixture for the bricks is a very simple process, but still needs an expert laborer. Traditionally, the most common way is to combine the materials of soil with appropriate amounts of sand, silt and clay by kneading or mixing. The soil is mixed with an appropriate amount of water, straw or other materials added, all mixed together to a workable consistency. Straw or sturdy grass is often added to increase the durability of the bricks, providing some measure of tensile strength. Other materials can also be added. Mixing of the raw materials to a specified consistency can be done by various methods – traditionally by stomping it with feet. Once mixed, the forming and drying is relatively straightforward (Fig. 6).

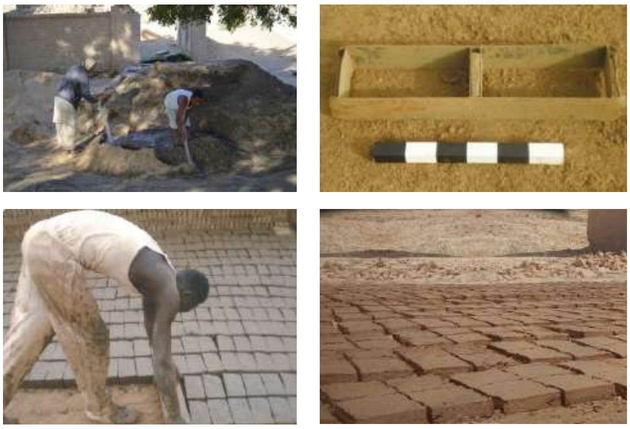

Figure 6: Preparing the mud brick for restoration.
© A. Adam

The mud is then formed in a mold, the mold is removed, and the bricks allowed to dry in the sun. Despite a few minor differences in techniques and mixes, preparation is uniform throughout the world, and consists of three main elements. First, the bricks need a binder to hold them together and make them strong. For this reason, a subsoil of clay is the crucial ingredient. Second, to further increase the durability of the bricks and to give them tensile strength, fiber is added to the mix. Lastly, the mixture is poured into a form that gives the brick its shape and size. Original bricks from the building to be conserved or restored are measured and the molds made to those specifications. Some of the earliest bricks were formed in small holes in the ground (Fig. 7).

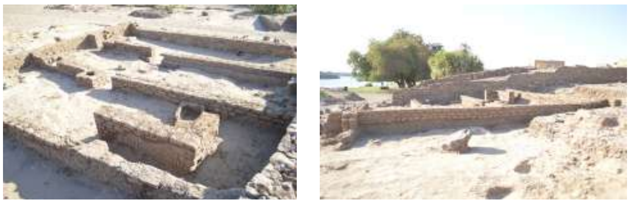

Figure 7: Restorated walls and buildings foundations.
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4.7. PLASTERING

Traditionally houses are usually renovated before the fall of the year. A quantity of animal dung, especially that of donkeys, is prepared and added to the wheat straw or what is known as hay, with the addition of a certain type of soft soil, which is known locally as *Regaitaa* owing to its high smoothness. It is important for this not to be of the type of 'cracked' dirt, which is carefully selected. This material is then mixed for at least a week until fermentation occurs and is then re-kneaded for one or two days and then used to fabricate the mud or brick walls using trowel and *Taloche*. The latter is a local tool made of iron and helps in the smoothing and solidification process and makes the plastered material smooth and coherent as it dries. It then becomes very solid for at least three years. The mud and straw were kneaded in such a manner that the product was well-made and solid (Fig. 8a and 8b).

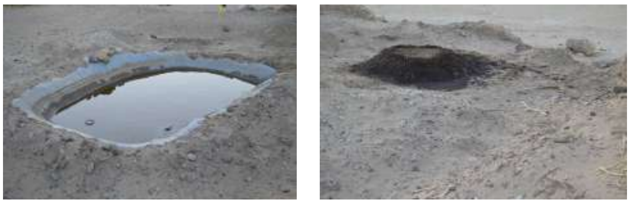

Figure 8a: The stage of preparing the material for plastering.
© A. Adam

We have applied all these technologies in the maintenance and restoration of the buildings of Khandaq City from my personal experience in this field. I have a long experience in the construction and restoration of mud buildings, which helped me to do so in the city of Khandaq city. The results have been remarkable.

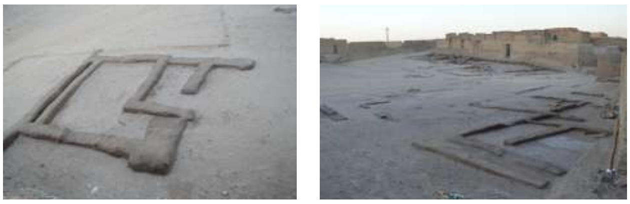

Figure 8b: Plastering the wall and foundations of some houses.
© A. Adam

5. RESTORATION

Fractured and eroded walls are restored with coherent mud or mud bricks depending on the need and type of construction to be restored, and then allowed to dry for at least 3 days before the plastering operation begins. It is very important not to use sheep's animal dung because over time they produce the earth bug that erodes clay buildings.

The Khandaq buildings were observed to be very sturdy and solid despite the age of their construction and the lack of periodic maintenance. This could be due to the durability and the quality of the mud used in the construction. Also, the region has not seen regular heavy rains. However, partial climate change due to the establishment of the Meroe Dam has led to rainfall in recent years, which is considered dangerous for these buildings, and requires maintenance, which is one of the objectives of the historic Khandaq city project.

5.1 CASTLE WALLS AND TOWERS

The Castle was constructed of stone and mud and the restoration required the same materials that were used originally. The stone was brought from a quarry and a certain type of coherent soil was also brought to use as mortar so that the shape of the building would not change. The actual restoration was by local builders with expertise in the construction of stone buildings. Most of the overall shape of the towers was completed so that the local population thought they were the original buildings (Fig. 9).

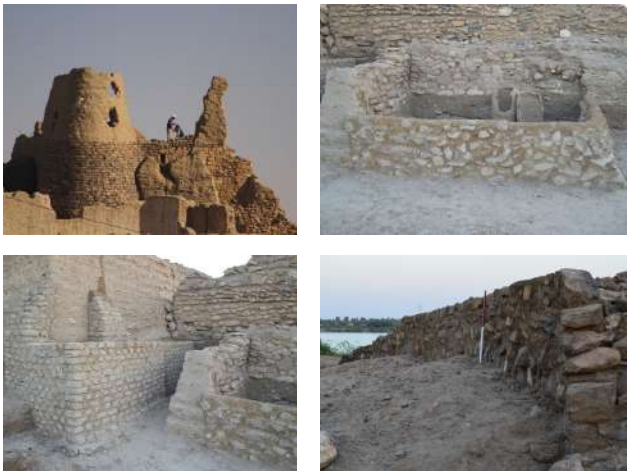

Figure 9: Walls and towers maintenance.
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5.2 CITY STRUCTURES

One of the most difficult and important challenges is the maintenance of all the buildings in the city because they are unique and are the only model of the multistory mud buildings remaining in the Sudan and most are in good condition. The current population has greatly welcomed the restoration and maintenance programme to keep them from disappearing.

Our plan envisaged the restoration and reconditioning of previously unknown walls discovered during the archaeological work and the reconstruction of some standing buildings in the city. In the course of this work, a list of the historical monuments built of mud brick was drawn up to schedule them for restoration using the basis of the extra experience obtained during the work.

The state of deterioration in some sites was such that it required extensive work immediately work, such as the southwest wall for which the director of the project required an engineering team to do urgent conservation work, which is not complete. In general, the mud-brick buildings are two stories with medium and small rooms supported by stone pillars, wood, and brick arches at both levels.

One of the most important techniques is the replacement of missing parts. The original mud bricks of an architectural structure constitute a historical testimony which, in principle, should be preserved as far as possible in the replacement of deteriorated mud bricks. The object is to produce a uniform result, and so the mud bricks employed should not therefore be of marked contrast to those characteristics of the pre-existing structure.

The restoration of the second tower of the fort, the northwest tower, I carried out based on experience gained from experiments made with different techniques for mud-brick walls. For example, the mud brick composition was tested, as cattle dung was added along with cut straw, and a corresponding reduction in the amount of gravel. We found that the preparation of traditional mud bricks with quality control resulted in the best quality. Hence, the experience acquired in previous restoration work was used to restore the mudbrick of this fort towers and walls.

Climate change-related impacts pose challenges for the maintenance of mud buildings. Traditional construction methods may need to be adapted to address the changing climate and ensure the durability of structures, efforts to address the impact of climate change on mud buildings in North Sudan may involve a combination of resilient construction techniques, community awareness, and sustainable land management practices to mitigate the effects of climate change and protect vulnerable structures.

CONCLUSION

Sudanese mud buildings exemplify the sustainable use of local materials, traditional craftsmanship, and cultural heritage. While modern construction practices are emerging in urban areas, the conservation and continuation of traditional mud building techniques play a vital role in preserving Sudan's architectural legacy and ensuring sustainable construction practices for future generations.

Developments in construction and in related technical fields have been generally prompted by the need to improve housing quality These experiences, and the participation in the project of several specialists who have been working on the improvement of mud-brick design, permitted the extension of this approach to historical monuments made of mud brick, with special emphasis on improved systems for consolidation and conservation.

The results of the restoration aspect of the project have been successful, and the methods used have preserved the structures for the last five years. Examples of the restoration work performed at Khandaq testify to the splendid work which has been carried out there during recent years using appropriate technology.

There is still work to be done. Future studies of the local climate, soil conditions, local building practices, comprehensive climate and building monitoring programs are important for the effectiveness of future restoration projects. Programs, workshops, and seminars which engage local communities in the importance of preservation and the preservation process will also have long-term benefits. Partnerships with NGOs and International Organizations specializing in heritage conservation can bring additional expertise, funding, and global visibility to the preservation efforts. The development of training programs for local artisans and craftsmen; a comprehensive database documenting historic mud building, including their architectural features, history, and current condition will also be extremely important to future projects.

One of the most important conclusions which may be reached from this work is that, with local technology and limited resources, it is possible to overcome nearly all restoration and conservation problems. The restoration of mud-brick buildings described in this study constitutes a part of the general problem confronted, but there are other areas of Khandaq with other building types and building systems which are also important and will require additional time and studies in the future.

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COMMUNITY ENGAGEMENT IN EARTHEN HERITAGE CONSERVATION IN THE WESTERN DESERT IN EGYPT

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SUMMARY

In Egypt, the western desert preserves some significant examples of earthen architecture, such as the cities of Al-Qasr, Balat and Mut. These examples illustrate the traditional Saharan architecture typical of the Egyptian desert and reflect Egypt's cultural diversity. Al-Qasr is considered the most intact example of the vernacular architecture of Ottoman towns developed in the 17th century.

Earthen architecture is vulnerable and threatened by urban decay and physical degradation. Still considered as primitive and rarely documented, it however represents a wealth of sustainable traditional building techniques rich in intangible associations. Al-Qasr is a site whose heritage is contested and, consequently, so is the community's involvement in the conservation cycle. The fringes where the two worlds - state and community - meet could in fact constitute a new mandate for future community involvement in the conservation project.

This hypothesis has been studied within research undertaken in 2015 within the "Youth Employment Project for the Conservation of the Islamic City of Al-Qasr", funded by Japan and UNDP and hosted by the NGO AlRashda under the supervision of the Ministry of Tourism and Antiquities. Participatory Action Research (PAR) has been proposed to document local community perceptions and suggest appropriate and sensitive solutions with adopting both ethnographic and anthropological approaches. This method has emphasized the importance of working with the local community in conservation practices, including perpetuating people's know-how and skills.

Keywords: Earthen Architecture, Ethnographic approaches, Participatory Action Research, Anthropology of development, Climate change, Environmental degradation, Sustainability

INTRODUCTION

Earthen buildings can be found all around the world. Yet, traditional earthen buildings and settlements are an expression that near to 20% of World Heritage properties are earthen architectural structures[1]. There is a significant amount of existing work on the physical conservation needs of earthen buildings shown for example by the work of ISCEAH[2]. The role of building knowledge is increasingly emphasized by the social turn of conservation and heritage and yet there are few examples of the undertaken approach in which Al-Qasr's documentation would provide an example of co-creation, documentation and understanding of these cultural practices.

1. OVERVIEW OF AL-QASR OLD TOWN: HISTORY AND GEOGRAPHY

In Egypt, the Western Desert still preserves some significant examples of earthen vernacular architecture towns, one of the aspects of Egypt's cultural diversity. These illustrate the outstanding Saharan traditional architecture typical of the Egyptian desert where people used sustainable architectural patterns and building methods[3] to both shelter from, exploit but also preserve the surrounding environment and present a positive energy-saving architectural design. The old town of Al-Qasr (Fig. 1) is one such example. It is located in Al-Dakhla oasis[4] in the western desert, 800 Km SSE of Cairo and 250 km west of Luxor. Al-Qasr and Mut towns are the two main towns of fourteen settlements in al-Dakhla. North of Al-Qasr is a limestone cliff and the other sides are surrounded by cultivated fields and palm groves. The geographical location of the town of Al-Qasr has historical importance, as it is at the meeting point of pilgrimage and trade routes, such as Darb Al-Jubari, Darb Al-Tarfawi, and Darb Al-Tawil, through which caravans were coming from the Maghreb, the Hejaz, and southern Africa. This was a major reason for merchants and princes to settle there, which was reflected in the outstanding architectural richness of the buildings. The old town known as Al-Qasr was established by the sides of a Roman fortress (with still remains of it) but attained greater importance during the Ottoman period during which it had become the capital city of the Oasis[5].

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[1] Unesco 2016.
[2] Cooke 2010.

The climate of the Al-Dakhla Oasis is the same as that of the Western Desert, where rainfall is scarce and the maximum temperature in July reaches 50-55 degrees and drops to 0-4 degrees in January[6].

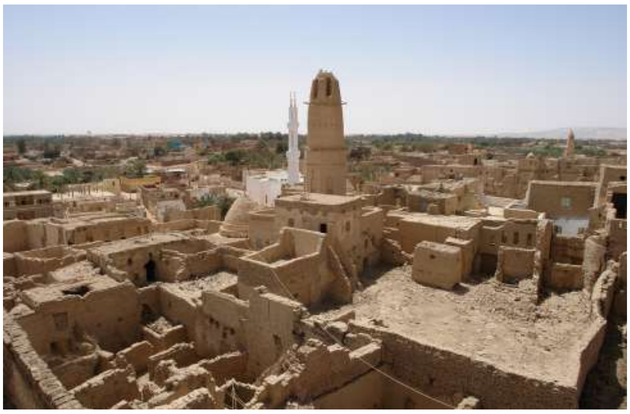

Figure 1: Overview of Al-Qasr Old Town.

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2. SETTLEMENT TYPOLOGY

The old town of Al-Qasr is an example of sustainable community adaptation where the culture of collaboration is evident in the planning of the Old City. It developed to create a typical feature of Islamic desert architecture[7]. The settlement is shaped into a compact defensive structure with bonded mud brick walls. It has a mosque in the center, connected with narrow alleys separating the houses allowing a clear organization with differentiation between public and private areas to preserve the social system which requires segregation between the activities of daily life (economic and religious) and domestic life.

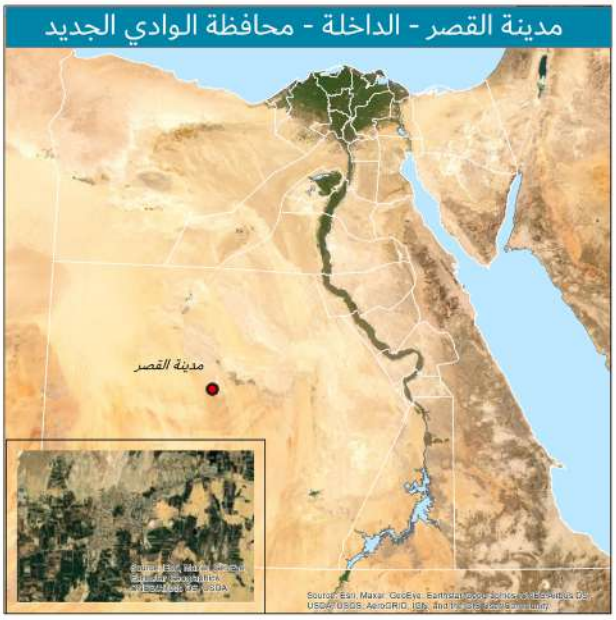

Figure 2: Location of Al-Qasr Town in Western Desert.

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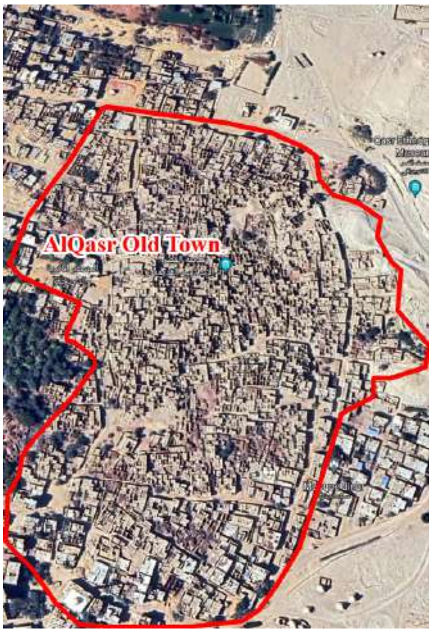

Figure 3: Aerial photo of Old Al-Qasr Planning.

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The houses are connected to the outer walls and consist of three or four stories. The ground floor consists of an entrance that leads to a courtyard allowing to access a variety of rooms used for storage for food, cooking and washing facilities, as well as latrines. The first floor is intended for receiving guests while the second one is for women only. The terrace on the highest level is usually used to allow people to sleep outside on summer nights. The facades include wooden doorways with wooden lintels including the artisan signature and date of construction. Window openings are semi closed with wooden screens called masharabiya to access lighting and air[7].

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[3] Alnahas 1990.

[4] One of the three main oases of the New Valley Governorate, the other two being Al-Kharga and Al-Farafra oasis.

[5] Shehab 2001.

[6] Balbo 2006.

[7] Shehab 2001.

Traditional earthen building methods and techniques are inherited from generation to generation. As a result, this kind of architecture/town planning illustrates the ecological and sustainable character of traditional design and techniques to meet defensive and social needs, adapted to the oasis environment where the local materials are extracted[8].

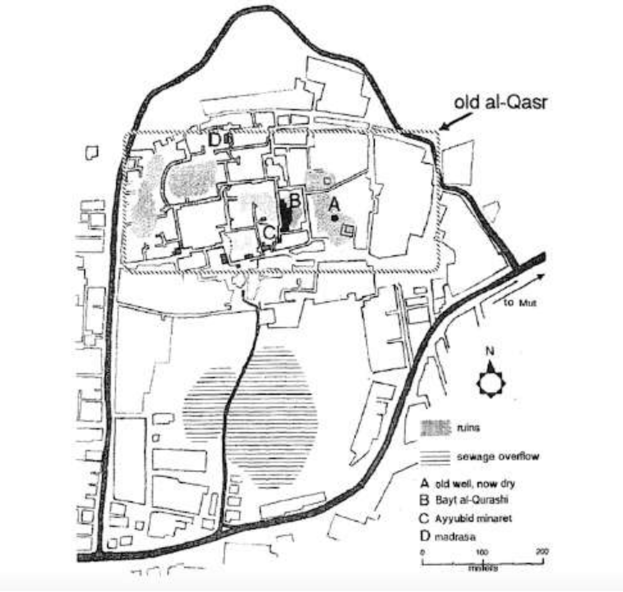

Figure 4: The plan of the Old Town.

© Shehab, 2011

3. CONSTRUCTION PROCESSES

Construction practices are the responsibility of family members, including soil selection, mixing by hand or foot with the addition of fine rice straw, sand and goat manure, using specific measurements to avoid cracking. Mud bricks used are casted in wooden molds and dried in the sun.

The design of the houses is different depending on social class, economic activities and needs of the inhabitants. Still the construction process remains similar. The first phase is the laying of the foundation which is made using limestones. That constitutes the base on which construction is continued using mud blocks laid with mud mortar.

Besides mud bricks, timber beams are used to reinforce the structure, while wood is also used for the windows and doors lintels. Floors and roofs are constructed from acacia logs, palm ribs, palm leaves, mud mortar and mud bricks.

The whole structure is then covered with a sand-rich earthen plaster to form a flat and smooth surface. The mixtures and methods used are from local knowledge. The use of goat manure is much appreciated as being considered to repel insects and prevent cracks.

The production and construction phases are gender defined with master builders and juniors working alongside a separate carpenter involved in construction. Women's roles in final rendering, decoration as well as in maintenance[9].

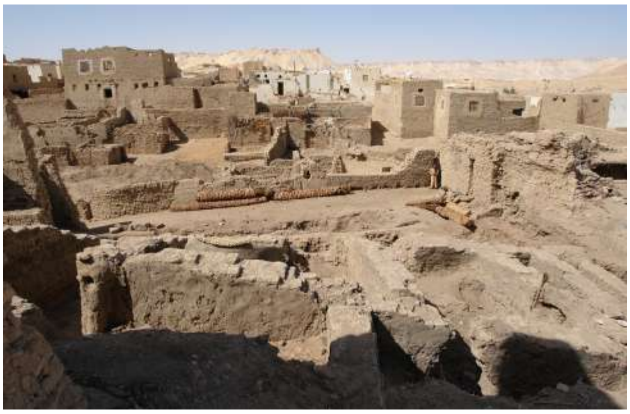

Figure 5: Severe structural degradation.

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4. CONSERVATION CHALLENGES

In 1993, the Egyptian Ministry of Antiquities (MoA) recognized Al-Qasr's unique character by registering it as a property belonging to the Egyptian state. Recently, the MoA also sought to have Al-Qasr included on the Tentative List of Egypt, as a first step towards inscription on the World Heritage List of UNESCO. In an attempt to preserve Al-Qasr's built heritage, the MoA has imposed constraints on alterations or maintenance of the old houses, and has also established a process in 2014 to reduce the number of inhabitants from 4,500 to 700, with no new residents allowed.

These policies have led to the abandonment of Al-Qasr, resulting in the gradual dismantling of the original fabric due to the lack of maintenance of the old buildings[10]. Al-Qasr ongoing socio-economic transformation and modernization represents a further challenge for the preservation of the old town historic urban landscape. New strategies are therefore needed to save the heritage.

5. DEVELOPMENT AND CHANGE

In 1959, the Egyptian government planned to establish the New Valley Project, in order to expand the urban area as an effort to increase economic productivity. The government then adopted modern housing models built with modern materials such as concrete and steel, to meet the needs of modern life, but these attempts led to a break in the social structure as it brought about major changes in the traditional use of private and public areas and consideration for traditional practices, economic, social and cultural.

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[8] Di Fillippi 2006.

[9] Dabaieh 2011.

[10] Di Fillippi 2006.

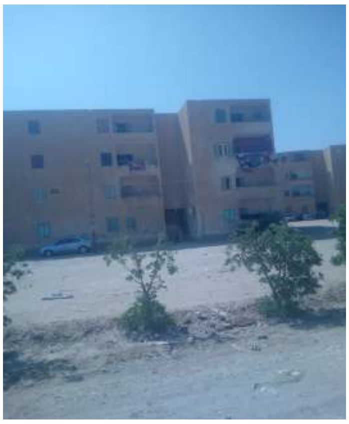

Figure 6: New modern houses, Al-Qasr Village.
© S. Fouad

As a result, this transformation led to a shift in the preferences of the younger generation, from traditional earthen architecture to a new, modern housing model[10]. Ultimately, the transmission of building knowledge and techniques has gradually disappeared and today, the younger generation is rarely enthusiastic about inheriting this knowledge from the old master craftsmen.

6. THE PROJECT OF YOUTH EMPLOYMENT IN THE CONSERVATION OF ISLAMIC AL-QASR

Over the past decades, the United Nations Development Program (UNDP) is developing partnerships to promote increased human well-being in the Arab region. The project is determined to promote employment opportunities towards better securing the future of the young population.

One of these projects is the Youth Employment in Al-Qasr Islamic City Conservation project funded by Japan and UNDP that aimed at improving the well-being of youth I the oasis by creating employment opportunities. It was started in 2015 and lasted for a year and a half. The project was to implement two specific UN policies, one on gender equality and the other on women's empowerment.

The director of Al-Rashda NGO (informant) stated that "the project employed 95 men and 35 women from the local community and their age was around 30 to 35 years old, while women do not have employment, men work on farms. The population of Al-Qasr is 7,500 people, 80% of the population are working on farms while the rest are affiliated to governmental institutions".

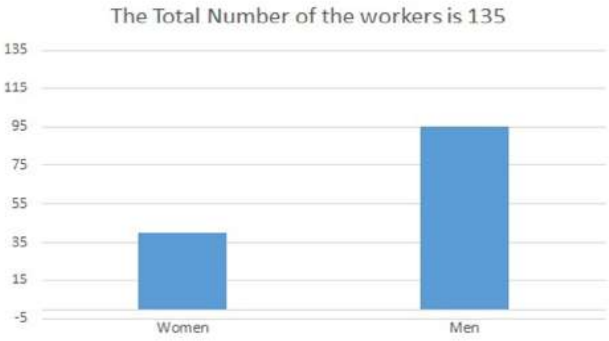

Figure 7: Total numbers of participants.
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This project is considered the first experience where young people were employed and engaged in the conservation project of four earthen architecture houses without prior knowledge of construction techniques. This idea was a first of its kind, especially since these young people are from the city of Al-Qasr and their ancestors are the ones who lived in and at times even built the ancient city of Al-Qasr and the bearers of this cultural heritage. The participants were divided into groups, some carrying out carpentry work, others preparing mud bricks and building, while still others were engaged in all wood and palm work and made ropes from palm leaves.

The conservation project began by carrying out a condition assessment to identify deterioration factors and required interventions. Next, an analysis of the soil, foundations and construction materials were necessary. That led to the assessment that all buildings had suffered severe damage processes such as disintegrating of walls, fall of roofs, doors and windows. Finally, the lack of regular maintenance, the difference between daytime and nighttime degrees, as well as sandstorms are additional factors causing further damage to the structures.

The four chosen buildings which required rapid interventions, were the following: Elmahdy Awadia house, Abu Ismail Mill, Abu Abdelmoaim house, sons of Abu Ismail house, and two Sebat. The work began by cleaning the houses of dirt, bricks and dilapidated walls. After that, the production and drying of the mud blocks was carried out, followed by the construction of the walls and finally the palm roofing was completed. Carpentry work, including the installation of doors, windows and slings, was the final step. The traditional earth buildings methods and inherited techniques were employed. The building practices initiated from choosing the soil, to mixing by hand or feet with the addition of fine rice straw, sand and goat manure, and the casting in a wooden mold and drying in the sun.

The construction phase was started with setting up the foundation with limestone at the base and mud blocks above it for about 30 cm. Alongside mud blocks, timber wooden beams are used to reinforce the structure, and wood is also used in windows and door lintels. Roofs are constructed from

Acacia logs, palm ribs, palm leaves, mud mortar and mud bricks. The whole is then covered by sand-rich earth plaster to form a smooth flat surface.

Women's roles are in the cleaning the ground from dirt and preparing ropes and their contribution in final rendering and decoration. The earth building mixtures and methods used are locally distinctive, for example the use of goat manure is considered to keep insects away and to prevent cracks.

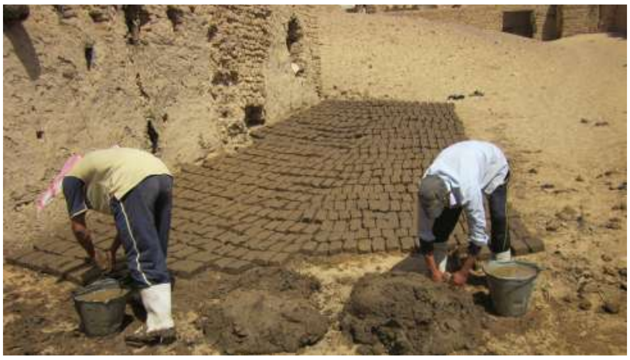

Figure 8: Preparing the mud brick blocks.
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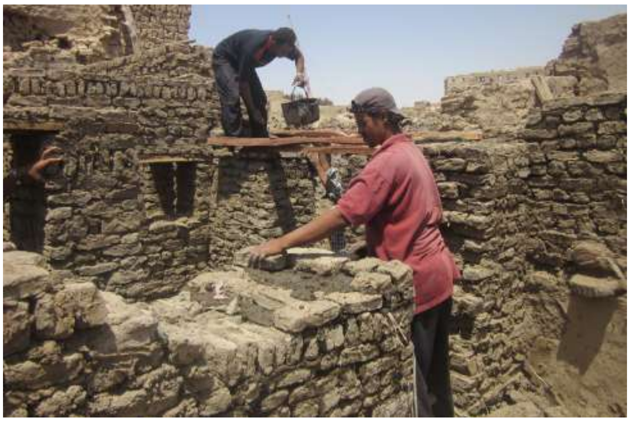

Figure 9: Wall construction process.
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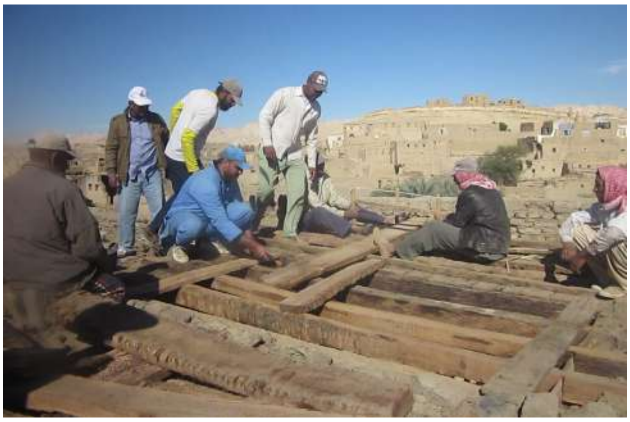

Figure 10: Fixing the palm beams on the roof.
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7. RESEARCH OBJECTIVE AND METHODOLOGY

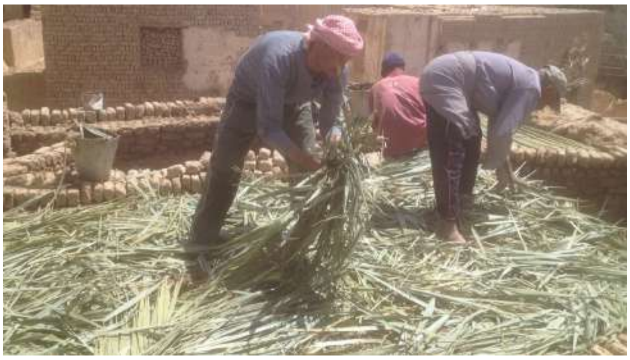
The main objective of our research was to evaluate and highlight the impact of the integration and engagement of the local community in the conservation of the cultural heritage project. Besides that, the presence in the oasis was also considered as an opportunity to try to understand the effect of climate change on Al-Qasr.

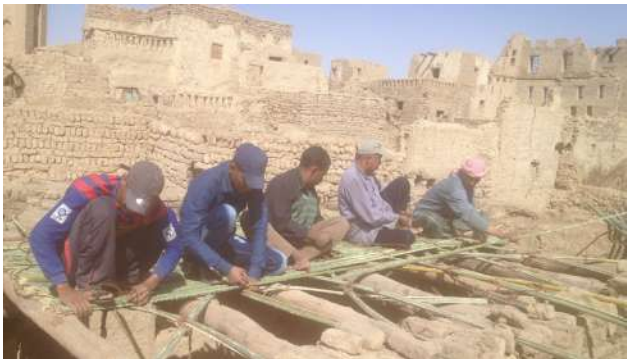
To that end, ethnographic approaches have been adopted to document the local community perceptions on the heritage and its evolution within time. Participatory action research (PAR) has also been proposed to document the people's views and preferences and further examine and explore the change that had happened after the project (as compared to before it) and its impact on improving the perception of the importance of the heritage values of the old town of Al-Qasr through raising awareness between the participants and their families.

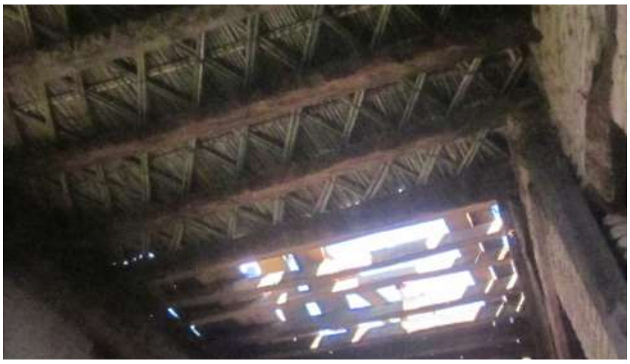
Two field studies were conducted in the Al-Qasr old town before and after the project to produce two ethnographic studies. The first ethnographic study that served as a base had been undertaken in 2008. This study aimed to conduct a survey to document the local community views about their socio-cultural values and its traditional approaches for conservation of the original site. It will also assess the impact of the current conservation policies on preserving the cultural heritage of Al- Qasr town. This survey explored what are the underlying causes of the current situation and how the views of the inhabitants' (community) and MA's (official state) differ. As will be highlighted, in what ways do these two views, community and state, differ in terms of strategies for conserving the cultural heritage. Also addressed is the question: What was the impact on both the local community and old town when the local community moved out of its traditional village to live in untraditional houses in Al Qasr Case, in terms of preserving their cultural and social values?

This resulted in a comprehensive documentation of the local community own perspectives on the perception of the values of the cultural heritage assets within Al-Qasr old town. Several methods of data collection were applied where PRA approach was employed, in which the participant-observation had been used during interviews with people from the local community. These semi-structured interviews were conducted with open-ended questions. These questions aimed to highlight their perspectives on the importance of conserving the old houses and what is the possibility of them returning to live in them. What is their feeling when they left their old houses to live in "modern" ones.

The second ethnographic study was carried out in 2017, it was to explore the outcome of the conservation project and achievements. The condition of the restored houses was observed and the view of the youth who worked in the project were investigate. Through interviews conducted with a group of 30 inhabitants involved in the project, with open-ended







Figures 11, 12, 13: Show the different roofing processes.

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questions. Those were to gather their perspectives and the experiences they gained, skills they had and their perceptions towards their heritage. Interviews also included aspects linked to climate change and its possible impact on the conservation of the old town.

8. RESULTS

The two ethnographic studies used revealed a number of very interesting issues:

The outcome of the first ethnographic study in 2007 had revealed that the youth rarely pay attention to local cultural identity and expressed that idea of living in mud brick houses without modern facilities was out fashioned. On the contrary, the old generation were deeply rooted in their heritage and highly appreciated the traditional houses are strongly attached to their culture and social identity.

The outcome of the second ethnographic study in 2017 has revealed that the employment of youths from the local community and their involvement in conservation processes resulted in about 60 participants having gained handcraft skills and further gained job opportunities leading to increasing the labor force in the cultural industry.

Moreover, a positive social and cultural impact was observed within the community resulting from the involvement of 135 participants in the conservation project, fostering dynamics of capacity building.

The groups of participants are considered as heritage transmitters, and bearers for their families as they are willing to participate in further conservation projects, thanks to women‘s role in spreading their experiences among their families.

Such engagement built cooperation among the local population, building a ‘sense of community’ that is paramount for further capacity development and conservation of local know how.

Figure 14: Interviews with project participants and people from the Local Community.

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Figure 15: Interviews with project participants and people from the Local Community.

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CONCLUSION

People have inherited the traditional way of building from their ancestors and this know-how has been passed down from generation to generation. However, socio-economic development has pushed people to abandon their old houses to live in modern housing models, resulting in abandoned and further damaged homes. Employing the local community in a conservation project is a positive instrument and an interesting driver to revive the sense of belonging and express pride and appreciation for the old vernacular mudbrick houses of their ancestors. In the studied project, cultural heritage was used as a tool to strengthen local identity, thanks to the year-long close engagement of communities in the conservation project of their surrounding built heritage.

Anthropology and anthropological approaches are very good tools to be able to measure impact on heritage conservation projects outcomes. The application of ethnographic techniques and PAR contributes to the understanding of the human dimension in the conservation process. Furthermore, the application of anthropological approaches can lead to the creation of a new model which is that of "conservation by and for the community", which means that the local community will be a driving force for its own sustainable development. Ultimately, anthropological approaches help create a connection between individuals and conservation sites, thereby making local people an active contributor to the conservation process.

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MITIGATION AND ADAPTATION TO CLIMATE CHANGE IN THE CONSERVATION AND PRESERVATION OF THE ARCHITECTURE AND FUNERAL LANDSCAPE IN QUBBET EL HAWA, ASWAN, EGYPT

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SUMMARY

On the western coast of Egypt, high-ranking officials and members of the Elephantine elite chose the east-facing hill of Qubbet el-Hawa as a cemetery. Until a few decades ago, when these tombs remained untouched, the environmental conditions inside remained constant. However, the process of exhumation and excavation of many of these tombs in the necropolis has accelerated their deterioration. Additionally, the impact of climate change, including increases in interior temperature and relative humidity, has further compounded to the problem. This research proposes a method for evaluating the impact of future climate scenarios on the preservation and conservation of tombs. An experimental method was followed, combining analytical formulations and in-situ measurements. The climate change scenarios predicted for 2030, 2050, and 2100 were based on the projected temperature variations. The case studies focused on the Qubbet el-Hawa tombs located in Elephantine.Data obtained from the monitoring campaign carried out in these tombs were used to validate simulation models. Design Builder, Energy Plus, and Dialux Evo software were used to generate models that replicated the tombs in detail, simulating indoor environmental conditions. One of the main conclusion of this study, is that measures to ensure the preservation and conservation of this heritage should be the reduction in fluctuations in relative air humidity and UV radiation in the interior space.

INTRODUCTION

Climate change poses a threat to the preservation of monuments and natural heritage sites worldwide, and it is crucial to protect them from its impact. At present, there is a commitment to integrate the preservation of world heritage into climate actions and strategies to mitigate and adapt to global warming.

The Egyptian funeral architecture and landscape are at risk of disappearing in less than a century due to the effects of climate change. Increasing exposure to the extreme changing climate could leave a footprint that endangers one of the most significant monuments for humanity, as highlighted during the last COP27 in Egypt.

According to the IPCC (Intergovernmental Panel on Climate Change) document, there are four possible scenarios of climate change, known as Representative Concentration Pathways (RCP), which consider climate policies (IPCC, 2014). These pathways represent a theoretical projection of greenhouse gas concentration (not emissions), adopted by the IPCC. At present, four different pathways for future climate change modelling (RCP 2.6, 4.5, 6.0, and 8.5) can be distinguished according to radiative forcing ranging from 2.6 W/m^2 to 8.5 W/m^2. These RCPs are associated with policies which aim to limit 21st-century climate change. In the case of RCP 6.0 and RCP 8.5, this radiative energy reaching the earth does not reach its maximum until 2100. For RCP 2.6, it reaches a maximum and then decreases, while for the intermediate scenario of RCP 4.5 it reaches a maximum in 2040 and then decreases until it stabilizes towards 2100. This last scenario could cause a global temperature increase of 2-3°C and a 35% average increase in sea level (Mugiyo *et al.* 2002).

1. DETERIORATION, CLIMATE AND IMPACT OF CLIMATE CHANGE IN EGYPT

The climate and geography of Egypt play a crucial role in the preservation of Egyptian tombs, as the desert environment in which they were built has influenced their construction and deterioration over time. However, their conservation is now at risk due to the effects of climate change, which in turn also puts them at risk of deterioration. (Moreno Cifuentes 2013).

Floods and torrential rains caused by the changing climate have resulted in the deterioration of some of the tombs. In response, drainage systems and channels have been set up to control water, preventing it from entering the interior chambers (Köpp-Junk 2020). Wind erosion has also been a factor in the deterioration of the tombs, with the impact of sand particles causing surface abrasion on the walls. In recent years, storms and winds far more severe than any observed previously have been recorded in Egypt, and are also considered the result of climate change (Azouz & Salem 2023).

Factors such as high temperatures, high relative humidity, direct sunlight, and sudden changes in environmental parameters inside the tombs can cause disintegration and decohesion of the elements which make up these tombs, particularly in the lower areas of these buildings (Wing *et al.* 2018). In areas near rivers, high subsurface humidity and high temperatures can lead to water vapour condensation, which can form deposits on the materials of the tombs, leaving crystalline deposits causing the surfaces to disintegrate. Thermal fluctuations can also cause the dispersion or loss of material inside the tombs (Iamarino, Neira Cordero, Lovecky, & Ojeda 2021).

Overall, climate change poses a serious risk to the conservation and preservation of Egyptian tombs. Therefore, conservation efforts must take into account the effects of climate change in order to ensure their long-term preservation.

The phenomenon of water vapour condensation near rivers in Egypt can negatively impact the materials of these tombs (Duivenvoorden *et al.* 2022). The combination of high subsurface humidity and high temperatures causes water vapour to condense and accumulate on the surfaces of the tombs, typically during early morning and dusk, when the air is relatively cooler and more humid. During the day, when the air is dry and hot, the humidity evaporates, leaving behind any salts that were carried by the water vapour. These salts deposited on the surfaces of the tombs or penetrating them through capillarity form crystalline deposits capable of causing surface disintegration. Additionally, thermal fluctuations can cause material inside the tombs to disperse or be lost (Sakr, Mahmoud, Ghaly, Edwards, & Elbashar 2021).

Another factor to consider is that of direct sunlight on surfaces with Egyptian paintings, where continuous exposure causes discoloration of the pigments due to ultraviolet rays and an increase in surface temperature due to infrared rays (Iamarino, Neira Cordero, Lovecky, & Ojeda 2021). Egypt is very vulnerable to the effects of climate change. Furthermore, the Nile Delta is considered the most threatened delta in the world and one of the three most extremely vulnerable areas on the planet, affected by climate change. This fragility is due to the increase in high temperatures, the annual sinking of its coast, the rise in the Mediterranean sea level, and a lack of foresight and means of adaptation.

2. METHODOLOGY

This research project aims to analyse the current microclimate of the tombs and the consequences of future climate change. An analysis will be carried out on the environmental parameters for the preservation and conservation of funerary architecture in Qubbet el-Hawa, Aswan.

This section presents the methodology employed in this research, which is based on an in-situ experimental method combining in-situ measurements and analytical formulations simulated by software to predict the interior environment of the tombs. The in-situ measurements are subsequently used to generate simulation models for real buildings which are then validated.

2.1 CASE STUDY

This research focuses on the study of the double tomb belonging to the high officials Mekhu and his son Sabni (catalogued today as QH25 and QH26, respectively), members of the social elite of the community of Elephantine (Jiménez-Serrano 2023). This project is perhaps one of the most prominent in the necropolis, located at the southernmost end of the hill, creating a striking visual image looking over the island. The two monumental ascending ramps with a shared common space halfway up the slope, limited by a carved stone facade, are easily recognizable from a distance. Although originally intended as a burial site for Mekhu, it was later transformed into an expanded double tomb, a space excavated for father and son. The two thresholds connecting to the shared chapel appear as two large cutouts in shadow on the stone, flanked by numerous subsidiary tombs arranged on the common reception courtyard. The large worship chapel is perceived as a single space, although its design and composition clearly show that it is the result of two merged projects. Even so, it is possible to perfectly identify the worship axes of both spaces, connecting the threshold with the false door located in the niche, a sacred space par excellence which is protected both physically and visually by adobe walls.

Among the sea of circular and square section columns that invade the worship space, a series of panels are distributed as supports for images of the owners and their families, as well as false doors and funerary chambers. The position of these images, showing likenesses of father and son, and everyday activities such as hunting and fishing, guarantees that they receive sunlight through the two cutouts in the facade (Joyanes Díaz, Muñoz González, Martínez de Dios, & Ruiz Jaramillo 2022).

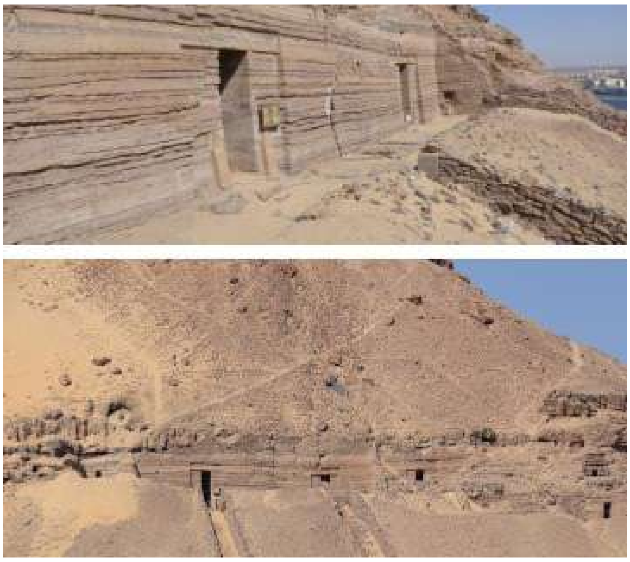

Figure 1: Tombs Q25-Q26.
© L. Joyanes Díaz

Tombs Q25 and Q26 (Fig. 1) were excavated in the necropolis in sandstone and lutites rocks, which is prone to self-destruction given its characteristic sedimentary nature. These rocky surfaces, as can be seen in the images, are not suited to carving or painting, so that in some cases, they have been covered with mortars and plaster to support a layer of decoration.
An initial inspection showed that the tombs had also been subject to natural deterioration together with the human actions, as intentional fire, provoked by ancient looters.

2.2 OUTDOOR CLIMATE

Currently, in Aswan, summers are very hot and winters are mild, but there are daily abrupt changes in temperature and relative humidity between day and night, reaching differences of up to 10-15ºC and 20-35%, respectively. The thermal jump is less pronounced in winter than in summer, although the difference in relative humidity is greater in the winter season than in the summer (see Fig. 2). In the early morning and at sunset, temperatures are lower and relative humidity is higher, while at noon temperatures rise due to the effect of solar radiation. These fluctuations in temperature and relative humidity can cause the mineral stone to expand, generating internal tensions.

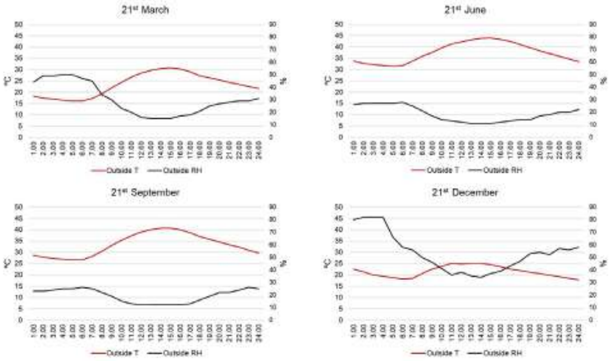

Figure 2: Hourly data of temperature and relative humidity in Aswan. 21st day.
© C. M. Muñoz González

The local wind, which is dusty, dry, and warm, lasts for about 5 months, and usually occurs between May and September, dragging large amounts of sand and dust from the desert and causing temperature rises. The predominant direction during this time is southwest, while for the rest of the year it is north and east (see Fig. 3). This environmental parameter is one of the most aggressive for conservation because it produces abrasion and excessive dry humidity affecting the stone. This causes changes and losses in morphology, producing rounded shapes. Additionally, this sand-laden wind penetrates into excavated tombs with no protection at the entrances, directly affecting the chambers and walls, wearing down the reliefs and polychromy.

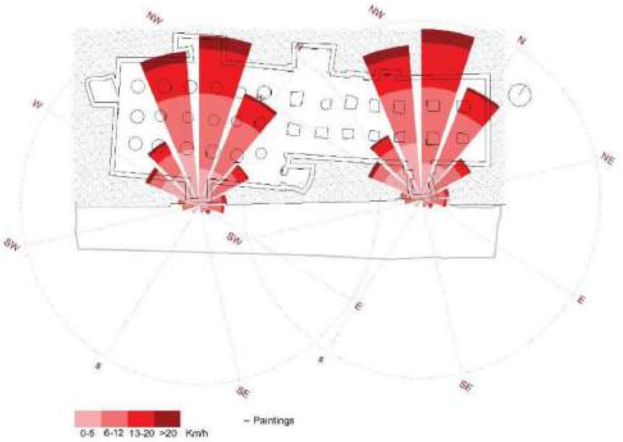

Figure 3: Prevailling wind direction.
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2.3 MEASUREMENTS AND COMPUTATIONAL MODELLING

Simultaneous measurements of temperature and relative humidity, as well as point measurements of lighting levels inside the tombs, were taken during several campaign periods from 2019 to 2021 (Jiménez Serrano 2019), (Joyanes Díaz 2021). The recording range was from -35 to 80ºC and 0-100%, with an accuracy of ±3ºC and a resolution of 0.03ºC, and ±2%

and a resolution of 0.05% in the case of relative humidity. Measurements for external temperature, relative humidity, wind, global radiation, cloud cover, and pressure were obtained from a nearby meteorological station.

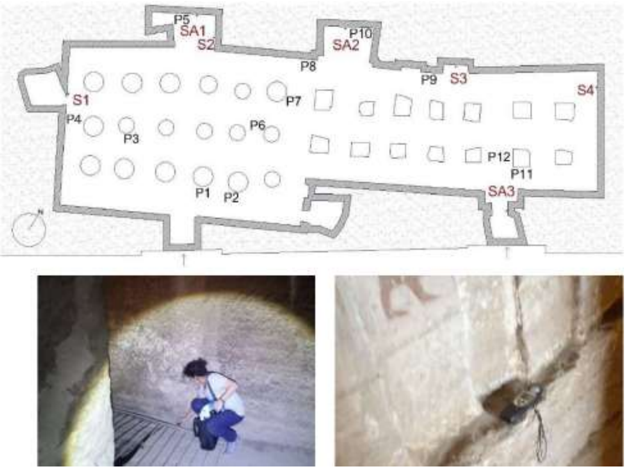

Figure 4: Layout of the tomb and location of the measurement points (S), painting location (P).
© L. Joyanes Díaz

A simulation model was generated to reproduce the interior and exterior, construction conditions, and materials of the tombs. DesignBuilder software, version 7.0.2.006 (Design Builder 2023), was used to simulate hygrothermal conditions indoors and lighting, and DiaLux evo version 10 (Dialux 2023) was used (see Fig. 5). These programs use Energyplus, Radiance, and Daysim calculation engines. The model was validated using monitoring data. The deviation between the in-situ results and the values obtained through simulations was evaluated using two statistical measurement indicators, following ASHRAE 14-2014 (Ashrae 2014): Hourly Mean Bias Error (MBE) and Coefficient of Variation of the Root Mean Square Error (CV(RMSE)) (Muñoz Gonzalez, Leon Rodriguez, & Navarro Casas, 2016).

The same validated tomb model was used to evaluate the impact of climate change in different future scenarios. This required the original climate data file to be modified, taking into account climate change for the years 2030, 2050, and 2100. Future climate files for the climatic zone were generated through Meteonorm 8.0 software and then incorporated into the simulation tool. This software provides access to more than 8,000 meteorological stations and presents three IPCC climate change projections, RCP 2.6 (low), 4.5 (medium), and 8.5 (high), based on the Coupled Model Intercomparison Project CMIP5. The characteristics of these scenarios show the possible variability throughout the 21st century. The RCP 2.6 scenario is the closest to the goal established by the Paris Agreement, while the RCP 8.5 scenario is the most unfavourable, with a high increase in temperature and serious effects on the planet. RCP 4.5 was used for the purpose of this study.

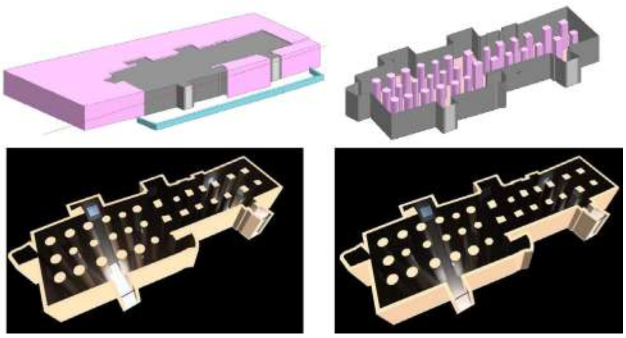

Figure 5: Software used in this study, DesignBuilder and Dialux Evo.
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3. RESULT

In Figure 6, several box plots based on quartiles are represented in order to visualize the set of hourly values of the temperature of the tombs. These graphs provide information on the minimum and maximum values (determined by the lines), quartiles Q1 (25% of data), median (50% of data), and Q3 (75% of data). They provide a general view of the symmetry of the distribution of temperature and relative humidity data and their dispersion in different seasons of the year. The summer and winter months present a symmetrical distribution and minimal dispersion with respect to the median (a concentration of data is found). In the case of the autumn and spring months, the symmetry continues, but the dispersion of values increases in different climatic scenarios. The range between the maximum and minimum temperature in the summer months is 3°C, in winter and spring 5°C, and in autumn it doubles, reaching a difference of 10°C. In the case of relative humidity, the greatest dispersion occurs in autumn, with up to 35% difference, while for the rest of the year, the dispersion is 10-15%. Although it is observed that the dispersion in autumn is greater at present, in future scenarios it will decrease, due to the increasing temperatures.

In order to establish suitable environmental parameters for the preservation of the tombs, various factors, including annual mean data, seasonal cycles, and short-term fluctuations, must be considered. The following graph shows the recorded data for temperature and relative humidity, as well as indicating the annual mean of these parameters, which in the current case are 25°C and 27%, respectively. Similarly, the seasonal changes inside the tomb throughout the year are shown. To determine if the current environmental conditions can cause mechanical damage to the walls, short-term daily fluctuations of both temperature and relative humidity inside the tomb were calculated. Figure 7 summarizes the daily fluctuations and presents the limits established according to ASHRAE, oscillations of ±2°C. The percentage of temperature fluctuation values outside the band is minimal, 2%, increasing to 3-4% in scenarios 2050 and 2100. According to these results, interior temperature fluctuations do not pose a serious risk to the preservation of hieroglyphs and paintings.

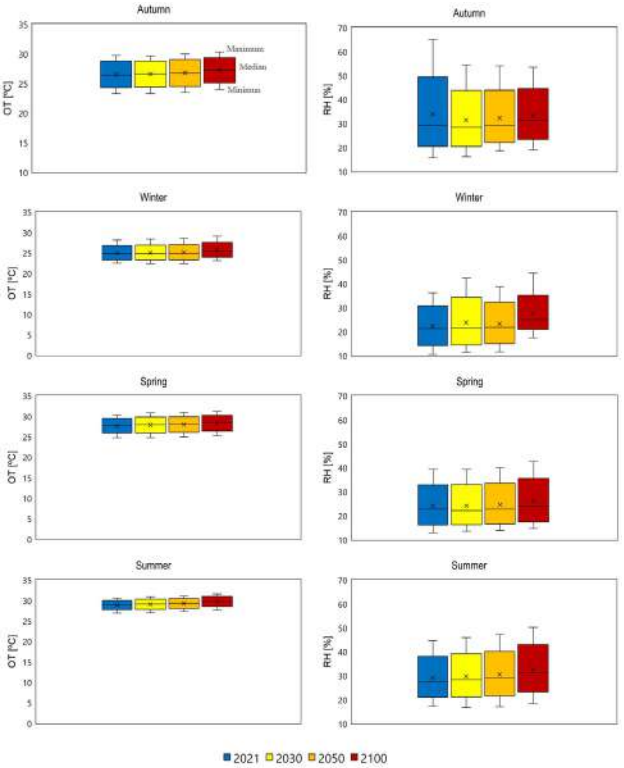

Figure 6: Statistics, the quartile, median, maximum and minimum T and RH.
© L. Joyanes Díaz, C. M. Muñoz González

According to the normative requirements of UNE-EN 15757, the lower and upper limits of the reference interval for RH fluctuations are the 7th and 93rd percentiles of the simulation fluctuations, respectively. In both instances in this case study, this is 7%. According to the results obtained in the current situation, there is a risk due to the deviation of this parameter for 20% of the time, worsening during the autumn months and during nighttime hours. The impact of climate change worsens the current situation, so that this percentage increases to 22% for 2050 and 25% for the year 2100. This parameter should be considered given the low mechanical resistance of the limestone composition of the tomb, which can easily break into slabs. It also has high porosity and moisture absorption capacity.

The Egyptian terrain is characterized by having organic compounds that, with the contribution of underground moisture and high temperatures, make it highly fertile for plants and vegetation, as well as generating biodeterioration stains caused by microorganisms present in the soil. These organisms easily develop at a temperature between 20-30ºC and with a relative humidity above 65%. According to the analysis of the data obtained, currently biodeterioration does not pose a risk to preservation in this tomb, as these environmental thresholds are exceeded during only 1% of the time in autumn. Similarly, in future scenarios, due to the increase in temperature, a decrease in relative humidity is expected, so that it will not exceed 65%.

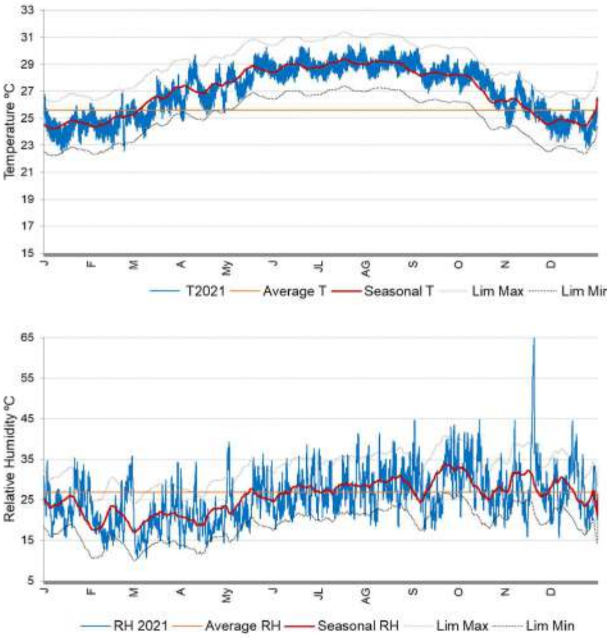

Figure 7: Monitored average T and RH and seasonal average limited.
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Another environmental parameter to consider is solar radiation, which combined with high temperatures causes a sudden decrease in humidity or continued UV radiation, causing colour loss over time. In this tomb, the colours in the polychromatic hieroglyphic inscriptions are altered or lost in some cases due to natural lighting or mechanical risks.

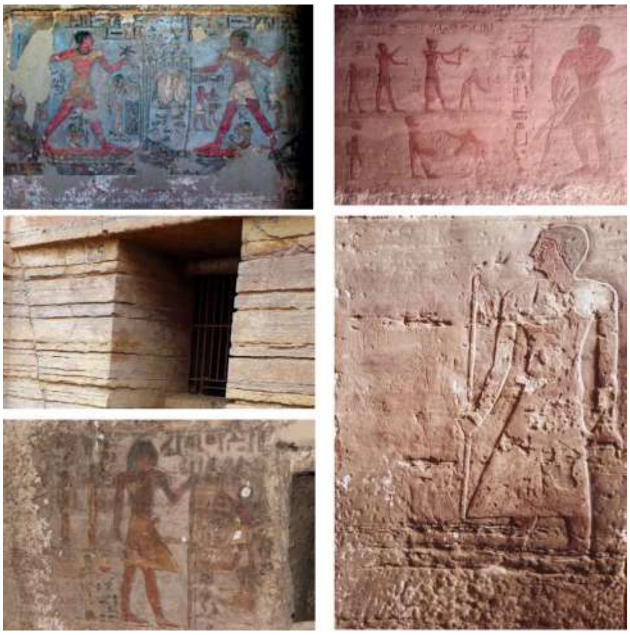

Figure 8: Deterioration of painting inside QH25 and QH26.
© L. Joyanes Díaz

In an initial visual analysis, it was observed that hieroglyphics with reddish colours are better preserved than those with bluish colours. This is explained by the fact that the colour red is made with a natural oxide that is very abundant in the area, providing resistance and stability. However, the colour blue is artificial and is generally created with a mixture of silica, calcite, and copper minerals, which are less stable under unsuitable environmental conditions, becoming more brittle and even taking on greenish tones. In this tomb in particular blue is used in the hieroglyphics located in the niches of the pharaohs, which are less exposed to natural lighting and have more stable climatic conditions.

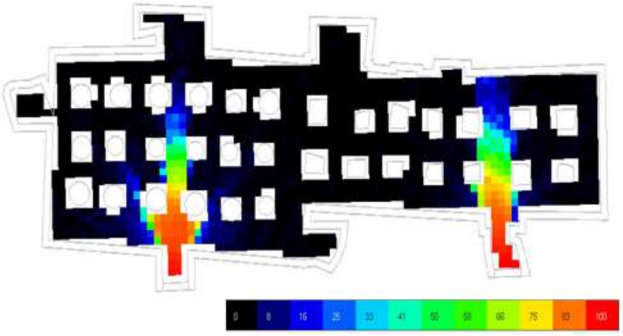

Figure 9: Annual hours of natural lighting (nighttime hours are excluded).
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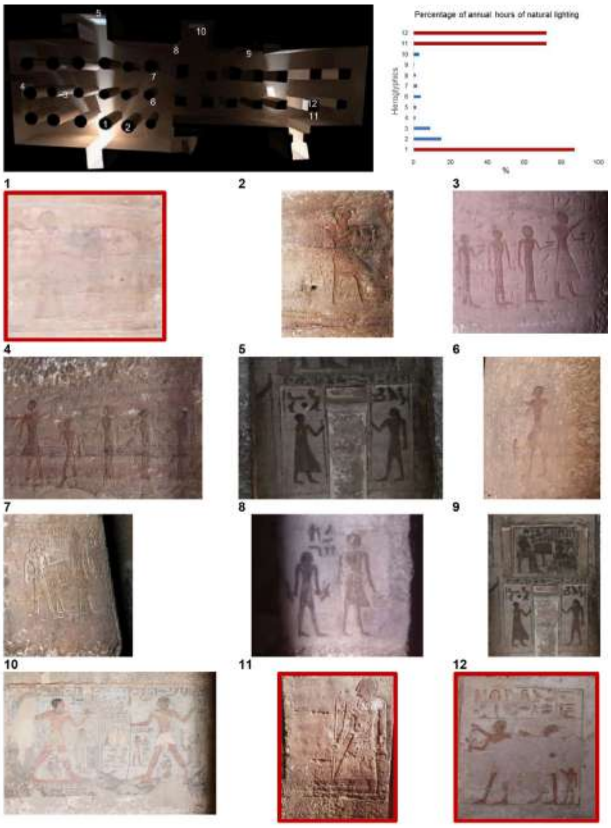

Figure 10: Percentage of annual hours of natural lighting on hieroglyphics.
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As expected, according to the results obtained from computer simulations (Fig. 9), it has been observed that hieroglyphics more exposed to natural lighting present greater deterioration (Fig. 10). The hieroglyphics marked in red, present a greater number of hours of exposure with high light intensities. Considering that Aswan has around 3988 hours of sunlight throughout the year, it is observed that the areas closest to the entrance and central areas have a higher percentage of lighting time, around 80-87%. Similarly, these hieroglyphics present a greater colour loss and more deterioration pathologies due to fragmentation or erosion.

The incidence of UV radiation is expected to increase in future climate scenarios, which will be affected by changes in the stratospheric ozone. The decrease in stratospheric ozone allows more UVB (the most harmful type of UV) to reach the Earth's surface, so that hieroglyphics could deteriorate further, accelerating their disappearance, unless preventive strategies are designed.

Finally, Figure 11 shows colour change due to exposure for four hours a day at an intensity of 200 lux and 400 lux, in three different scenarios (2030, 2050 and 2100). The results determine that the colour intensity, and even all the colour, could disappear in under 50 years due to exposure. By 2030, the colour intensity would be lost, but the colour could start to disappear for the remaining scenarios.

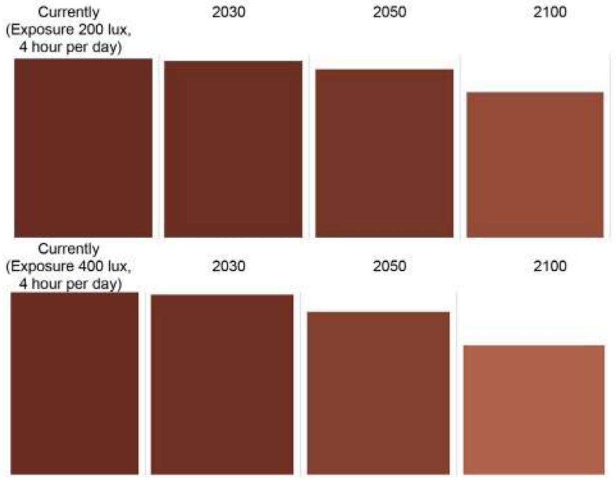

Figure 11: Fading of a single colour in three different scenarios.
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CONCLUSIONS

This research addresses the conservation and preservation of funerary architecture in Aswan, Egypt, in the face of climate change. The study uses an experimental method combining in-situ measurements and analytical formulations to evaluate the impact of future scenarios on the tombs. According to the analysis of the results, current environmental conditions are not suitable for the preservation of hieroglyphics, mainly due to variations in humidity, natural lighting, and wind incidence. The localized damage to the hieroglyphics is primarily due to erosion caused by sand impact and mechanical damage generated by indoor environmental conditions. It is necessary to reduce fluctuations in relative humidity and the incidence of solar radiation and wind impact in order to improve the current microclimate and future scenarios.

This preliminary study is necessary to assess risks and plan adaptation strategies for the tombs. Thanks to the application of these technologies the current and future situations, and the environmental impact of future project strategies aimed at improving these, can be assessed. The conclusions of this study will be used in future research for environmental conditioning and tourism projects for the tombs.

ACKNOWLEDGMENT

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ŠĪR-DARWĀZA HISTORIC WALL: AN ARCHITECTURAL AND HISTORIC STUDY FOLLOWED BY A CONSERVATION PROPOSAL

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SUMMARY

My study focuses on a military monument located in the city of Kabul in Afghanistan, which includes the historic city wall of Kabul, known as Šīr-Darwāza, constructed between the 6th and the 9th century by the descendants of the Hepthalite dynasty. The monument is partially preserved today, and is referred to as the "Kabul Šīr-Darwāza Wall."

This historic wall of Kabul comprises earthen architecture and is the oldest and most popular monuments of Kabul. It is located to the northeast of the old town, and is considered a national monument. The wall starts from the west part of the citadel, and with a length of around 3 km, crosses the top of the Šīr-Darwāza Mountain and joins the Kabul River on the other side. The mountain on which the wall is located divides the city of Kabul into eastern and western parts.

Today, only a few parts of the wall remain. As the site has been a battlefield throughout history, from the arrival of Muslim Arabs until the British, then during the Soviet invasion and the civil war right up to the present day, it has experienced lots of damage and destruction. The remains consist mainly of sections of the wall on the mountain. The objective of this research is to conduct a global study of this historic city wall and to try to render its different components through existing sources and photographic data. It also includes a study of the current state of its conservation, degradation process, and threats towards its conservation. The article concludes with a concrete proposal for the conservation of the wall and by highlighting the important place of the Kabul Šīr-Darwāza historic wall in Afghanistan Cultural Heritage.

INTRODUCTION

Situated on some significant stretches of the Silk Road, Afghanistan is a country with a long and rich history. From the Bronze Age through the ancient Persia, Graeco-Bactrian, Kushan, and Hepthalite eras to the Islamic period, the region has been influenced by its network of international trade routes and by its neighboring kingdoms. This complex history has given rise to significant archaeological, artistic, and architectural cultural heritages all over the country. As a result, today's Afghanistan possesses one of the most diverse cultural heritages in the region.

Because of its strategic location, the country has frequently been the pathway of foreign conquerors and invaders throughout its history; therefore, one of its particular types of architectural heritage is associated with military purposes. This military architecture reached its peak during the Hepthalite Era, when many military forts and citadels were constructed, some of which still remain along the ancient silk road, and which have particular construction materials and architectural styles.

In this article, I present one of the most important and particular example of the above-mentioned military monuments, which is Kabul's historic city wall, known as Šīr-Darwāza. From the arrival of Arabs until the British invasion in the 19th century, The Šīr-Darwāza wall played a vital role in defending the city of Kabul and its inhabitants from foreign attacks, and as a result the wall experienced lots of damage, destruction, and reconstruction.

Today only around 30 percent of the structure of the Šīr-Darwāza wall remains, on the top of a mountain with a similar name. Therefore, to better understand the history and the current condition of this site and its monuments, this article summarizes the historical background of this monument and continues with a comprehensive study of the wall before concluding with a proposal for its better preservation and management in the future.

1. HISTORICAL CONTEXT

Located in the east of the country between 34° 31' 01" North and 69° 07' 59" East, Kabul is the largest city in, and the current capital of, Afghanistan. According to written sources and archeological remains, it is one of the oldest cities in Central Asia. The city covers an area of 950 km^2 with a population estimated at around 5 million.

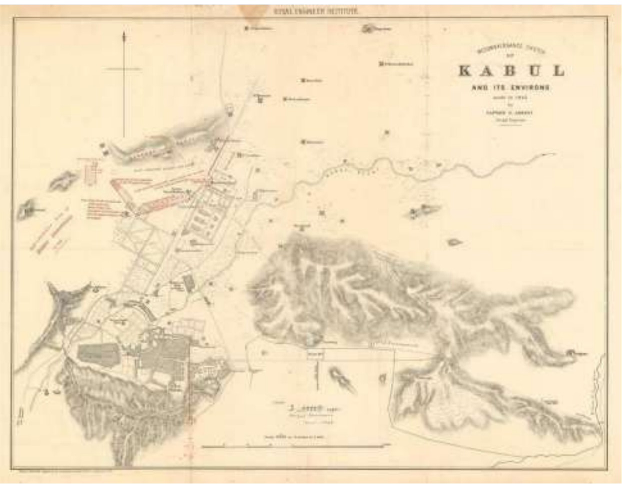

Figure 1: Sketch of Kabul city in 1879.
© Captain F. Abbott

The city has had a very eventful history since its foundation. Because of its important location on the Silk Road, it has always kept its economic and geographical importance. We do not know much about its existence before the Kushans and the Hepthalites, but the name Kabul started being recorded from the time of the arrival of the Hepthalites[1]. The existence of several Buddhist monasteries around the city also shows the importance of this area during the Buddhist rise, as Buddhism was the official religion of the Kushan and Hephthalite dynasties. Arab forces arrived into the area in 870 CE, besieging the Kabul fortress for more than six months, and the historic city wall played a significant role in keeping the enemy outside the city.

The Mongols attacked the city in 1221, and it experienced lots of damage and destruction. Tamerlane captured the city in 1398. Babur, the founder of Mughal Dynasty, captured Kabul in 1504, and the city became the first capital of the Mughal Empire[2]. In 1738, the city was occupied by the Persian general Nadir Shah, and following his assassination, Ahmad Shah Durrani seized power and established the Durrani Empire. His son Timurshah Durrani moved his capital from Kandahar to Kabul in 1773. The latter city then experienced lots of development, and the famous Murad Khani Quarter was constructed during this time to house the Qizilbash Forces who were accompanying Timurshah Durrani as his special guards[3]. The British army first attacked Kabul in 1842, and the war resulted in widespread destruction in the city, The second attack by the British forces took place in 1880 and resulted in the destruction of the Bālā Hīsār and considerable damage to the city wall. A decade later, during the rule of Amir Abdul Rahman Khan, the new palace which is the current presidential palace of Kabul, was constructed outside of the walled area of the old city, towards the north of the citadel.

Despite all these wars and the destruction they caused, Kabul has remained Afghanistan's Capital until today. Kabul is, therefore, a hybrid city, having traces of several civilizations in its fabric. But, unfortunately, the most recent forty years of war have disfigured it even further, and it has even become extremely difficult to imagine what the city looked like at the time when the Mongol Emperor Babur gave it the name of "Paradise on Earth."

2. KABUL HISTORIC WALL, KNOWN AS ŠĪR-DARWĀZA WALL

2.1. HISTORICAL BACKGROUND

Located in the east of Kabul Bala Hissar, The old city wall of Kabul, locally known as Dīwarī Šīr-Darwāza, is a historical monument initially constructed during the Hepthalite (Yaftalyan) Empire (450-568 AD). The wall is part of Kabul's ancient citadel (and was probably built before the citadel), and lies south of the modern city center at the top of Šīr-Darwāza Mountain (see Fig. 2).

There are different theories regarding the possible date of construction of this monument, but it was most likely built in the 5th century by King Ratbīl Shāh, a descendant of the Hepthalites, who ruled over Kabul and its surroundings. The specific purpose of constructing this wall around old Kabul was to defend the city from foreign attacks, as the other sides of the city were already protected by the Kabul River which formed a natural barrier.

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[1] Rising from the Pamir mountains of Badakhshan, the Hepthalites ruled over a vast empire stretching from Central Asia to Northern India from between the mid-5th to the 8th centuries. It is said that the city of Kabul was founded by the Hepthalites in around the 6th century BC.

[2] His successors established their capital at Agra in India, and Kabul remained a regional capital of the Mughal Empire until the arrival of the Persians.

[3] The Murad Khani quarter is still preserved and was recently restored by AKTC.

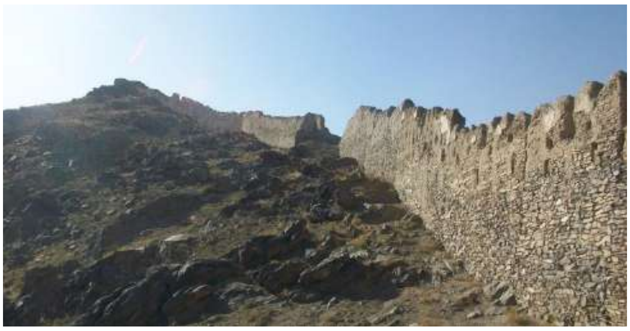

Figure 2: View of Šīr-Darwāza Historic wall.
© S.M. Khalili

Therefore, the king decided to build this wall over the two mountains (Šīr-Darwāza and Asmaī) to protect the city from attacks. As such, the major part of the wall was built over the Šīr-Darwāza Mountain. The wall is named after this mountain. Legend says that in the 6th century the Kabul King was so worried about the security of his city that he forced all his male subjects to build a wall on the hilltops surrounding the town. Those that were too lazy, tired, or sick to work would be buried in the wall's foundations. The local peasants eventually revolted, killing the king and interring his remains along with the commoners he persecuted.

The nature of the materials and methods used in the construction of the wall, and evidence of several reconstructions and repairs, shows that the wall is a multi-period monument. The Kabul citadel was reconstructed and developed during the Timurid rule and most importantly during the rule of Babur Shah and his descendants after he moved his capital to Kabul, and then for a second time after the moving of the capital from Kandahar to Kabul by Timur Shah Durrani in 1773, and finally during the British occupation of Kabul. It is probable that some reconstruction and development of the wall took place during each of these periods.

2.2. GENERAL DESCRIPTION

Starting from the western corner of the Bālā Hīsār, the wall originally ran for some 5 km, traversing the Šīr-Darwāza mountain, one line running up to the Takt-e Šāh peak, and a second line descending into the Dehmazang gorge, where it crossed the Kabul River and ascended the Kuh-e Asmāī before going down its north face, terminating west of Deh Afgānān.[4] It is said that the wall once had six gateways located across its length, but none of these have survived.

Today, the parts of the wall on the Asmaī Mountain and through the Dehmazang gorge have completely disappeared, and I have not found any traces or vestiges of it in these areas. The current traces of the wall, including the remaining part, have a length of about 3250 m and end on the banks of the Kabul River.

2.3. HOW THE WALL WAS CONSTRUCTED

Various construction systems were employed in building the wall. The construction of each part seems to have been adapted to the nature of the earth and the availability of local materials. From the western corner of Bālā Hīsār up to a distance of around 500 m, the wall is built of cob (Pakhsa) with a base of locally quarried stones[5]. The thickness of the first part of the wall here, at the stone masonry base, is approximately 1.80 m, and it decreases with height of the wall. Pebbles and clods are used between every two layers of the cob.

Towards the moderately steeper part of the mountain, the wall construction method changes. Here, we find a marriage of two different materials in the construction, stone and mud brick (adobe), with a format of 25*25*6 cm. It seems that the bricks were fabricated elsewhere and then transported to the construction site. Here, due to the very steep slope of the land, the basement is very wide (about 4.5 m) and includes a space 3.5 m wide and 2.5 m high. Part of this base is used as a walkway, and the width of the wall itself upon this wide foundation is around 1 m.
The proportion of stone masonry and mud brick in the construction of the wall varies according to the earth contours. We can determine that 60% of the absolute height of the wall is built in stone and 40% in adobe, but this is not consistently the case all along the wall. The absolute height of the wall also differs depending on the earth contours, but is between 5 m and 7 m. The wall continues in the same shape until the most elevated part of the mountain. Arriving on the plateau at the top, the stone masonry retains the same width and is composed of local stones and earth mortar which was apparently made on site. Because of the demolished parts, it is difficult to determine the exact height of the original wall here.

Going down on the other side of the mountain, the shape of the wall follows the contours of the earth, but the construction technique changes, as do the materials used. Here, we observe the use of a stone foundation which resembles that of the other side, but for the upper part the adobes have dimensions of 35*25*10 cm, much larger than the adobes used on the other side.

In the last part of the wall, the height of the wall decreases to almost 3 m and the earth becomes rocky with an extremely steep slope, so it becomes difficult to move around. In this part, the wall retains the shape of a staircase with several steps, which gives it a pleasant aesthetic appearance (see Fig. 3). The mortar's thickness varies across the various sections of the wall, but remains between 3 and 6 cm.

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[4] Caspari, Dupree 2008.

[5] This technique is widely used in the region: the cob walls are applied in several layers, each one being left to completely dry before the next one is laid. Sometimes stones or wood are used between the layers to strengthen the wall in the event of an earthquake.

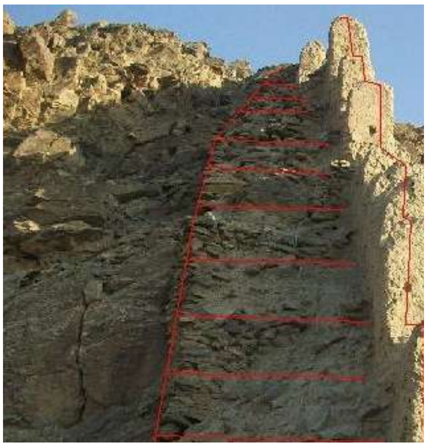

Figure 3: Remaining of the the wall towards the north side of the mountain, near Kabul river.
© S.M. Khalili (2009)

Regarding the coating, I have noticed that there were generally two layers of earthen plaster plus a lime paint. The base plaster consists of a mixture of earth and straw, and the finishing plaster comprises earth and sand. Lime paint has been applied to the interior facade of the wall.

2.4. THE PARTICULAR ARCHITECTURAL ELEMENTS OF THE WALL

As a military monument, particular architectural elements on the wall include:
- Turrets
- Arrow slits
- Cannon slits

a. Turrets

Turrets are squat military towers found in military monuments, normally located at strategic points to guard the city or the fortress. In this place, the turrets are placed along the wall, spaced out every 150 to 200 m. They maintain circular plans of 5 m in diameter with a staircase inside which allows access to the most elevated part of the turret.

b. Arrow slits

Arrow slits are openings in the walls of military monuments, through which soldiers could observe the arrival of the enemy and shoot them with the arrows. They are found in military fortifications, in various shapes. In the Šīr-Darwāza Wall, there are two types of arrow slits. The first are at the bottom of the wall, at an equal distance from each other along the wall, at the height of a seated man. They have a rectangular shape of 20*15 cm and cross the wall with a slope of about 35°, allowing defenders to shoot at enemies who had already arrived exactly behind the wall. The second row has each arrow slit positioned exactly above the first, 35 cm between them, which places them at the height of a standing man. They cross the wall horizontally and through them it is possible to monitor places very far from the wall. The arrow slits are set a distance of 80 cm from each other along the wall (see Fig. 4).

c. Cannon slits

The cannon slits are openings which look like narrow windows, which were considered to be passages for cannons. These openings are placed along the wall at a 12 m distance from each other. The cannon slits are some 50 cm wide and 70 cm high. They end with an arch made either of bricks or stone slabs. The adobes utilized for the realization of the arcs have a format of 25*25*6 cm (see Fig. 4).

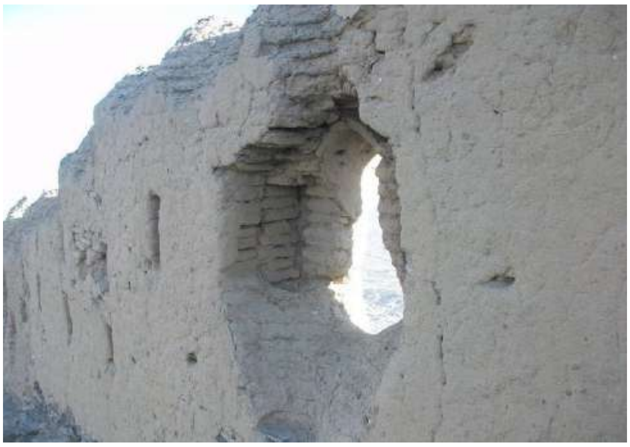

Figure 4: Arrow slits and canon slits in Šīr-Darwāza wall.
© S.M. Khalili

2.5. THREATS

The principal threats towards the preservation of the wall can be categorized as follows:
- Impact of severe weather (rain, snow, wind).
- Military usage of the site.
- The war.
- The rapid development of the city.

The combined impact of all the above-mentioned factors has meant that a considerable part of the wall has fallen into ruin, and the surviving parts are often gravely damaged.

2.6. DEGRADATION AND CURRENT STATE OF CONSERVATION OF THE WALL

Despite the major historical importance of this monument, so far nothing has been done for its conservation and maintenance. As a result, out of the 3250 m length of the original wall, only around 925 m remains practically intact. Around 1700 m of the wall has been totally destroyed by irregular development of the city. Some 525m of the wall is seriously damaged, meaning that there is either about half the wall left or just the foundations and the basement.

Some 475 m can be categorized as partially damaged. In some sections, we can see a partial degradation of the wall and in others there has been a merely superficial degradation of the plaster. In general, these parts were less used by soldiers. Finally, 10.85% of the total length of the wall, equal to a length of around 450 m, can be said to be well preserved. These parts of the wall are located in places where the mountain has a very steep slope and thus are the parts least accessible to the public. Unfortunately, in the present situation, with a lack of political will for conservation, the irregular devolvement in this part the city is rapidly continuing, putting the remainder of the wall in danger of destruction. It is therefore ultimately quite likely that this notable historical monument will be lost forever. Some recent photographs I have received from local sources show that the destruction of the wall continues due to weather erosion and illegal housing development around the historic wall. So, considering the above mentioned risks, an emergency restoration of the wall is required. Therefore, in this part of the article, a proposal is made regarding how to preserve the site in line with the authenticity of its monuments.

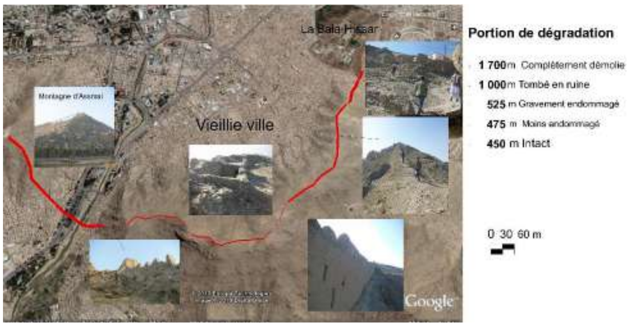

Figure 5: Sate of conservation of The Šīr-Darwāza wall.
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3. PROPOSAL FOR THE PRESERVATION OF THE SITE

As previously discussed, the wall is currently in extremely poor condition and if nothing is done to prevent more degradation and destruction, there is a significant risk of the severe deterioration and utter collapse of the wall in the near future.

3.1. HOW TO INTERVENE ON THE SITE?

The intervention activities depend on the condition of the remaining parts of the wall and must take into account the current state of the wall. Based on these considerations, three types of interventions can be considered:
1- Protection
2- Restoration
3- Reconstruction

3.2. WHAT TO DO FIRST?

Unfortunately, the wall has not been restored or repaired in last two centuries, and its preservation therefore requires a comprehensive project. Consequently, to ensure the success of the project, in the first place, coordination with local inhabitants and national authorities is required, to reassure the nearby population that they are the first beneficiary of the project and encourage them to take part in the implementation of the project. This will also ensure the maintenance and protection of the site in the long term, as the people who live near the site may perform an essential role in protecting it.

Furthermore, it is critical to think about the inhabitants who will have to be moved during the execution of the project, as some houses are built directly on the ruins of the wall, adjacent to it, or very close to the remaining parts of the wall.

3.3. PROJECT IMPLEMENTATION STRATEGY

Once the initial steps are taken, a public awareness campaign on heritage conservation and the importance of historical monuments is necessary. There is also the possibility of using local media outlets for this campaign.

As the preservation of the whole site at once would take a long time and require a lot of resources, the project can be implemented in 4 phases in parallel with an archaeological study:
Phase 1 - Preparation and Awareness
Phase 2 - Implementation of the project on the first part of the wall, built in cob (Pakhsa).
Phase 3 - Continuation of the project on the second part of the wall, built in stone masonry and adobe (Mud Brick).
Phase 4 - Restoration and rehabilitation of the entire wall.

3.4. PHASE 1

This phase of the project includes the following activities:
- Fundraising.
- Administrative steps.
- Building public awareness.
- Searching for local masons and craftsmen.
- Implementation of experiments and development of suitable restoration techniques.
- Set up a training site for local masons and craftsmen.
- Acquisition of building materials that cannot be found locally.
- Preparation of the necessary materials.
- Preparation of technical documents.

3.5. PHASE 2

The part of the wall chosen to be considered for Phase 2 of the project is the remaining part of the wall in which the cob construction system (Pakhsa) is used. It is the most easily accessible part of the wall for all kinds of visitors, including the elderly, young people, and children.

In this part we can use the earth found on the site for the restoration of the wall. The materials we would need to source and deliver from outside are straw and stone. The intervention on this part of the wall includes restoration, repair, and consolidation. As the site is expected to become an archeological park in the future, the construction of a reception and information desk at the entrance of the site is also expected.

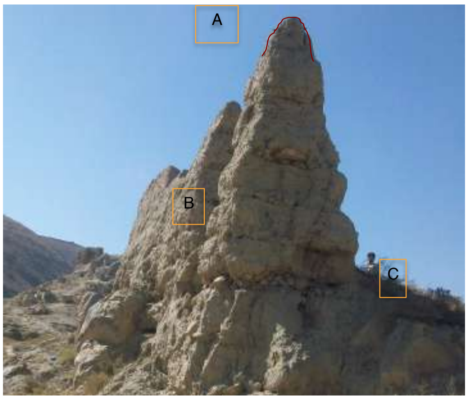

Figure 6: Part of the remaining cob wall near the citadel.
© S.M. Khalili

The stages of implementation of Phase 2 of the project are as follows:

a. Site Preparation
- Gathering the necessary tools and materials.
- Creation of access paths to the construction site.
- Site preparation.
- Carry out experimental tests on the selected part of the wall.
- Identification of traces of the wall (archaeology).
- Preparation of materials (stone, earth, sand, and straw).
- Adjustment of drainage slopes.

b. Restoration
- Repairing of partial degradation of the wall according to the original base (foundation, wall).
- Preparation of the wall surface.
- Application of the base coating (straw earth mixture).
- Application of the last layer of the coating.

c. Site management
- Preparation of panels and signage elements.
- Production of leaflets, brochures, and guides.
- Installation of panels at selected locations.
- Installation of signage elements.
- Construction of the information desk.

3.6. PHASE 3

Upon completion of Phase 2 of the project, Phase 3 can be started, which will cover the part of the wall built in adobe.
For the implementation of this part of the project, the required activities are similar to those outlined above for Phase 2.
In this part, we are dealing with an adobe construction technique on rocky terrain with an extremely steep slope. It will be necessary to fetch all the necessary materials from outside the locality, like earth, stone and straw. This means that it will be preferable to produce the adobes in the open area at the bottom of the mountain and then bring them to the construction site.

3.7. PHASE 4

Once the first 3 phases have been completed, we will move on to Phase 4 which is the final phase of the project. This phase contains conservation, restoration, and site management activities on the entire wall.
After completing the conservation and restoration work, we will move on to the management of the site, and then, once the management of the site is completed, the site will be open to visitors, and, in collaboration with the Ministry of Culture, a maintenance policy will be planned for the future.

The conservation of the entire wall will require the following types of interventions:
- Preservation in its current condition (with minimal intervention). This includes the following parts:
- Parts which have completely disappeared
- The parts fallen into ruin
- The severely damaged parts

Desirable works on these parts of the wall:
- Site clearance
- Site preparation
- Water management (improved drainage)
- Planning of access paths on the site
- Reconstruction of damaged wall sections
- Repair and recovery of the disorder that has appeared on the original masonry
- Resumption of elevations
- Application of layers of Superficial coatings for the protection of the wall
- Consolidation of the Foundation.
- Rehabilitation and management of the site.

4. CONSTRUCTION DETAILS OF THE PROJECT

In some photographs and sketches, how to restore or repair the damaged parts of the wall is explained (to better understand the details, please see the related photographs and sketches).

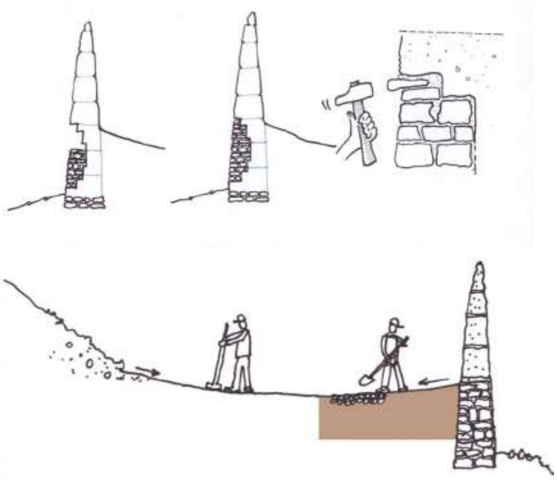

Figure 7: Realization of drainage slope and resumption of damage to the basement and the wall.
© D. Gandreau et S. Moriset

Detail 1 - In this photograph, an explanation of how to apply the repair process to a remaining part of the wall, built in cob, is given (Fig. 7).
A - Top to be protected with a layer of sacrificial mortar.
B - Repairing the damage to the cob wall and consolidation of the basement.
C - Cleaning and repair of the drainage on both sides of the wall with compacted earth.
Detail 2 - This sketch explains how to stabilize the sides of the wall using on-site materials and fix the drainage using compacted soil (Fig. 7).
Detail 3 - This sketch shows the repair process and how to fix the wall and basement damage with a minimal intervention by employing local materials (Fig. 7).
Detail 4 - Realization of layers of sacrificial coatings and protection of the top of the wall (Fig. 8).

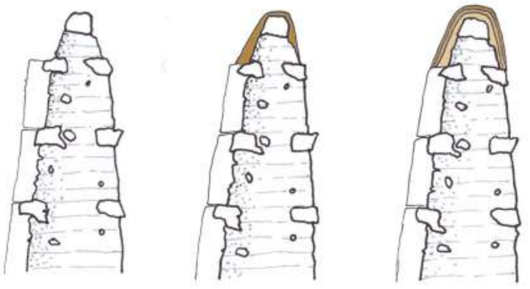

Figure 8: Realization of layers of sacrificial coatings, summit protection.
© D. Gandreau et S. Moriset

Detail 5 - The drawing explains how to restore the parts of the foundations which are currently in a ruined condition (Fig. 9).

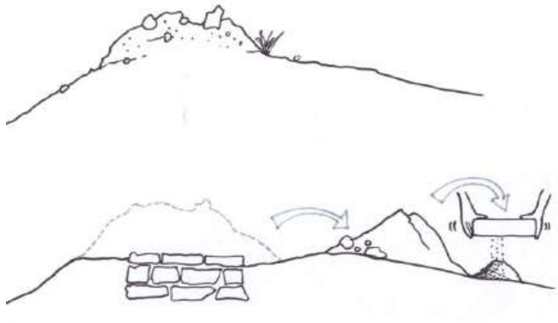

Figure 9: Restitution of the foundations.
© D. Gandreau et S. Moriset

Detail 6 - The drawing shows the condition of the wall before and after the restoration (Fig. 10).
Detail 7 - The photograph shows the various steps and types of intervention in the parts of the wall constructed in adobe (mud brick); this is the part of the wall which is preserved closest to its initial state (Fig. 11).
A. The peaks to be restored by applying layers of clay plaster
B. The recovery of partial damage and protection of the adobe wall by applying plaster.

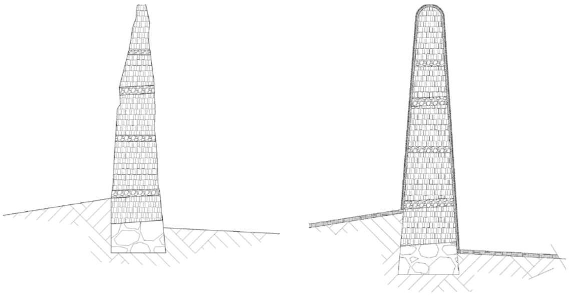

Figure 10: State of the cob wall before and after the restoration.
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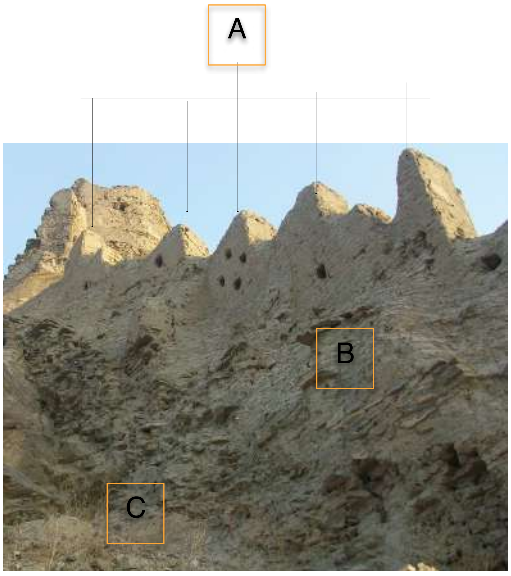

Figure 11: Detail of intervention for the part of the wall built in adobe.
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C. Restoration of the stone foundation after adjusting the drainage slopes and creation of a pedestrian path according to the ground slope.
Detail 8 - The drawings show the condition of the wall in adobe after the completion of the restoration (Fig. 12).

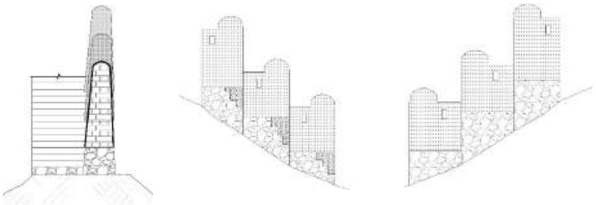

Figure 12: Drawings of The wall on adobe after restoration.
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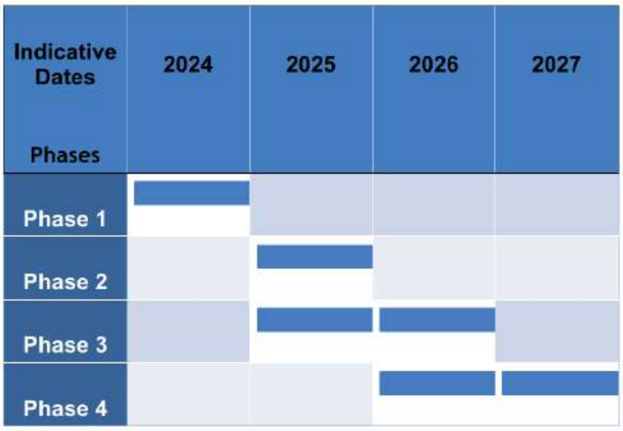
5. ENHANCEMENT OF THE SITE

The enhancement of the site takes into consideration the impact and importance of tourism which involves both national and local visitors.

The principal methods of site management are signage and routes. For this, we can cite the following suggestions and considerations:

- Road signs enabling access to the site from the city.
- A signboard should be positioned near the site to guide visitors.
- The indications provided by the signs can be extremely basic.
- Signs must be illustrated with diagrams, photos, and descriptions in three languages: Dari, Pashto, and English.
- A sign should be installed at the entrance to the site which illustrates the site plan and the visitor route, and other panels along the wall, as necessary.
- Dissemination of information on the site via guides.
- The quality of the signage, its location and its content should be appropriate.
- Leaflets, brochures, and guides to target tourists (foreigners but also local visitors), in order to involve them in the "rebirth" of the site.

6. THE PROPOSED ACTION PLAN FOR THE PROJECT



Indicative Dates Phases	2024	2025	2026	2027
Phase 1	■			
Phase 2		■		
Phase 3		■	■	
Phase 4			■	■

CONCLUSION

This article has aimed to highlight the history and current situation of the old city wall of Kabul, in relation to the environment, the local construction cultures, and future preservation of this site. Its content has mainly been the result of observations made during several visits by the author from 2009 until 2020, along with information received recently from my contacts in Kabul. Indeed, documentary research was very difficult, and when they existed, the documents often turned out to be very superficial, even containing information which did not correspond to what I observed during the field visits.

The Kabul Šīr-Darwāza Wall remains the most prestigious and remarkable monument of Kabul city. This monument is important not only for its historical and architectural value, but also potentially for its touristic value. Unfortunately, Afghanistan's cultural heritage in general, and this monument in particular, has profoundly suffered over many decades of war and conflicts, and the current situation in Afghanistan can be considered to represent a cultural disaster, as beside the ongoing insecurity and conflict, there are numerous threats to the preservation of Afghanistan's cultural heritage. These include the complete absence of a proper policy for the preservation of key monuments and sites, the fleeing of experts from the country, the absence of free media, the closure of international organizations, the lack of awareness of the importance and value of cultural heritage amongst the authorities, the suspension of legal protection frameworks, and the usage of the monuments for military purposes, in such a situation, the Kabul Šīr-Darwāza Wall is in danger of more damage and destruction, and if the present situation persists, Afghanistan could lose one of its most valuable monuments of considerable historic and architectural value. I therefore hope that this work will be a starting point for a much broader work on the conservation of this valuable monument. Finally, I'd like to add that very little research has been done with regard to the wall. So, this research has gathered the existing documentation on the history and architecture of the Šīr-Darwāza Wall, and some historic and new photographs and information acquired from local experts have made it possible to build knowledge about the origins of this monument, rewrite its history, provide an overview of its current condition. and offer a concrete proposal for its conservation.

Even if a significant part of the wall is completely demolished, this research allows us to highlight the importance of this monument and suggest how to deliver a better presentation of this important piece of cultural heritage in Afghanistan's capital. There is still a lot to do to give a more specific and accurate account of this site's origins and development throughout history, which will only be possible if some archeological works are carried out in the future.

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CONSTRUCTION DETAILS AGAINST MOISTURE IN ANCIENT BABYLON AND ITS SURROUNDINGS

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SUMMARY

Babylon lays in a semi-desertic environment characterized by high temperatures and elevated thermal excursions during winter, with differences of 30 °C or more. This difficult climate is co-existing with a very elevated presence of humidity showing in various forms: atmospheric moisture, rain- and ground water, condensation. Moreover, a high presence of salts is evident in the whole region where during dry seasons flat surfaces become white.

Temperature oscillation, moisture and salts together determine severe physical and chemical reactions and biological growth on and in adobe walls, resulting in a varied range of deterioration patterns. Historical constructors have evidently faced these concerns in ancient times and developed strategies to contain, when not eliminate, such threats.
An accurate observation of the archaeological remains unveils the peculiar know-how of ancient builders, who put up skilled strategies to contain effects of the raising moisture and presence of salts on earthen walls.

Examples have been investigated in different settlements in the Babil region, in Babylon, Borsippa and Kish. The ancient technological strategies observed are considered to be a great source of inspiration for the development of solutions for new construction.

This contribution is a first compilation of case studies and analysis gathered in the frame of the conservation works of the Ninmakh Temple in Babylon, a project coordinated by World Monuments Fund and the Iraqi State Board of Antiquities and Heritage (SBAH).

INTRODUCTION

This contribution reports some observations done during the assessment studies for the conservation of the Ninmakh Temple in Babylon, in the period January 2021 until now.
These observations have been registered in the archaeological sites of Babylon, Kish and Borsippa (the remains of these sites date to the new Babylonian period, 604–562 BC). The first ones have been done in the Temple of Ninmakh in Babylon, of which a more meticulous record of details is being kept so far.

What is visible today of the temple of the mother goddess Ninmakh (E2.MAH, which means "magnificent Temple") was mostly built during Nebuchadnezzar II reign (604–562 BC) even if there are very few remains that have been dated older (old Babylonian period 1700 BC - Assyrian period 626 BC). Due to the repeated raising of the level of the nearby Processional Way and the Ishtar Gate, the temple was rebuilt on higher levels several times during Nebuchadnezzar's reign. The first recorded excavation of a few rooms of the temple occurred in 1880 by Hormuzd Rassam working for the British Museum, and then later, starting in the year 1900, by the German archaeologist Robert Koldewey.

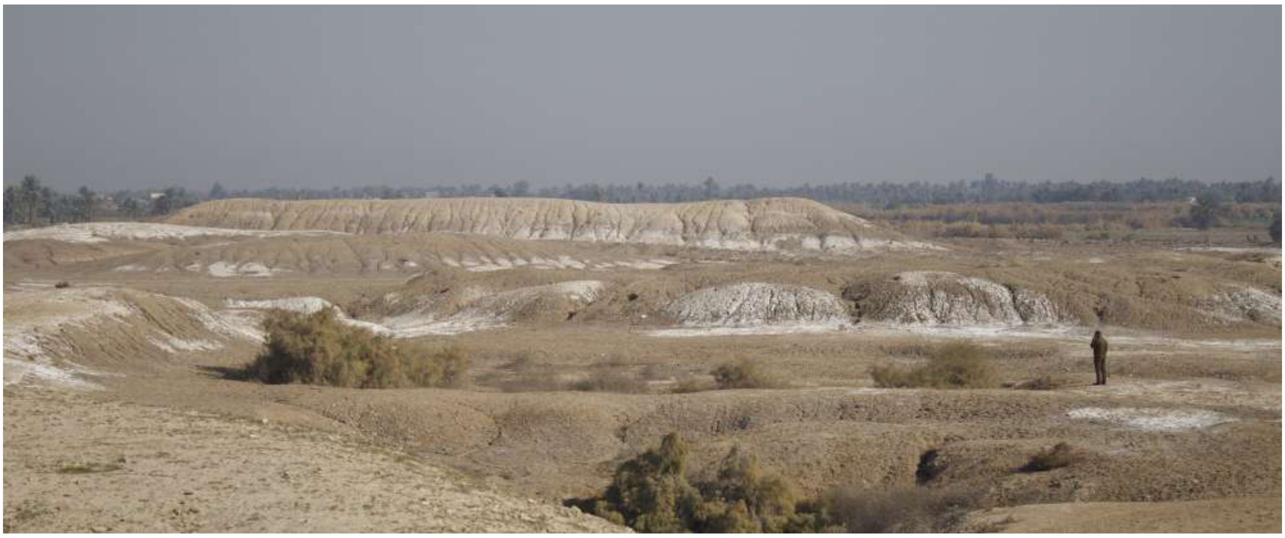

Figure 1: Tell Bander, Kish archaeological site.
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In 1961-1962, Iraqi archaeologists undertook excavations to a deeper level and reconstructed the temple on the standing original walls with newly produced earth bricks. No documentation was left to witness these works. The addition of an incoherent heavy concrete roof resulted later in its partial collapse leading to successive rebuilding of the exterior walls and roof during the following decades. After 2003, the lack of maintenance has led in the collapse of large areas of the roof and consequently also of some walls.
A recent activity of consolidation and restoration has been started by World Monuments Fund under the supervision of the Iraqi State Board of Antiquities – SBAH.

The preliminary studies of the temple, of its building elements and techniques, and especially the comparison with significant buildings at other sites nearby, highlighted a very interesting collection of historical strategies to address the presence of humidity in buildings.
The buildings considered for this article are the temples of Ninmakh, Nabûšaharê and Ishtar in Babylon, the Ishtar Gate in Babylon, the ziggurat in Borsippa and the temple of Kish.
Unfortunately, at this stage we cannot yet provide laboratory test results of the materials cited in this contribution, as the procedures for getting permission are still ongoing, but we are confident that we will be able to integrate them in the next future.

1. THE SITE

The Babil region, on which our investigation is focused, is located in ancient Mesopotamia, considered since early times the area between the Euphrates and the Tigris. In reality, over time, the use of this definition became broader, indicating Iraq, but also including partial areas of Turkey, Syria, Iran, Saudi Arabia and Kuwait.

The Babil region is located by the southern sections of the Euphrates carrying waters that come predominantly from the Turkish mountains. Due to the low precipitation, people who settled on the Mesopotamian floodplain are dependent on water from the rivers and on very well-organized irrigation.

The plain is also collecting groundwater from all surrounding areas. Heavy evaporation of the near-surface saline groundwater leads to salt accumulation on the surface, producing sometimes impressive effects on the landscape (Fig. 1).

Groundwater near the rivers may sometimes be useable for irrigation purposes, having a lower level of salinity (1–5 g/l), but not as drinking water, as the salt content is too high for this use. Because of this, the water of the Euphrates is traditionally preferred[1].

The area is also affected by a critical climate, with a dramatic oscillation of temperature which can be, according to the annual period, both cold (-5°C) and extremely hot (+54°C).
In the same way, dry seasons alternate with humid ones, determining a quite hard condition for human activities such as agriculture and herding. That also includes building practices.

Temperature fluctuation, moisture and salts together determine severe physical and chemical reactions and biological growth on, and in, adobe walls, resulting in a varied range of deterioration patterns. Historical constructors have evidently faced these concerns in ancient times and developed strategies to contain when not eliminate such threats.

Some techniques of prevention of moisture rise on earthen walls have been observed during the preliminary studies and data collection for the works of the conservation at the Ninmakh Temple and the Ishtar Gate in Babylon and in some other buildings of nearby sites: Kish and Borsippa.

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[1] Pedersén 2014.

The strategies observed are described in the following paragraphs.

2. STRATEGIES FOR PREVENTING MOISTURE CAPILLARY RISE

2.1 POSITIONING OF BUILDINGS

Commonly, as observed in settlements of any age and everywhere in the world, earth buildings are positioned in areas that are some meters higher than their surroundings. In Mesopotamia, too, iconic and representative buildings such as the ziggurat in Kish and Borsippa (Fig. 2), are located on barely perceived hills, well visible even from far. Though these sites are not yet fully excavated, we can still assume by logic that they were chosen to dominate the landscape. Experience from other similar sites informs us that this is a very common strategy to slow the capillary rise of humidity and keep sites safe from floods.

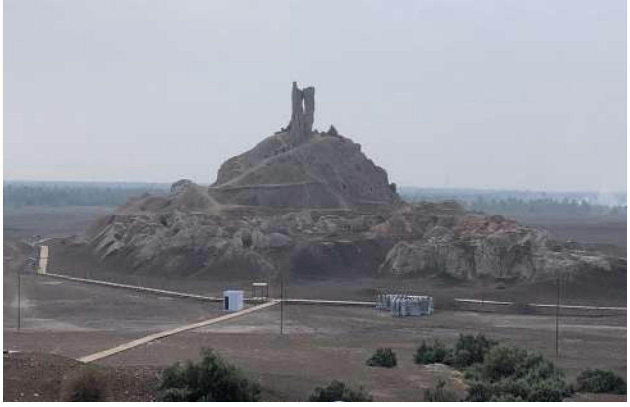

Figure 2: Borsippa.

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2.2 SLOPING FLOOR LEVELS INSIDE TEMPLES

Temples in the Babylon area have recurrent shape and internal distribution. They are built in paralepidid form, with an inner courtyard that serves as a connection to various chambers.
At the opposite side of the main entrance crossing the courtyard is the *cella*.

In Babylon, some temples have been rebuilt on their archaeological remains, in what has been called the new Babylonian style, following the original floor shape. Although no reports nor scientific documentation of the methodology that has been followed for their reconstruction is existing, thanks to some on-site surveys, we are quite sure that the historical ground level has been kept as a reference.

In all three temples analyzed in Babylon, Ninmakh, Nabûšaharê, and Ishtar, the *cella* and the other chambers are reached through a sloping floor that rises about 5 cm from the courtyard level. This difference in level is covered either with a step, to avoid water from heavy rains to come from the courtyard towards the sacred spaces. Supporting this, Koldewey reports: "*… at the gate (of the cella, editor's note) there's a channel which carried off the rainwater from the building*" [2].

2.3 USE OF LIME AS A PROTECTION FOR SURFACES

The use of lime plasters for external walls is recurrent in almost all significant buildings. Lime could be used mixed with earth, sand and ashes[3].

Lime, *noura* in Iraqi, used in Babylon was traditionally produced in the area of Karbala and it is still, even if its use in construction has decreased drastically in favor of cement. Nowadays lime is rarely used, due to its slow hardening and presumed lack of durability. After the experience of some builders interviewed, mixes are usually done with the following ratios of *noura* (lime) / sand:
1 / 6, mix preferred by less wealthy users;
2 / 9, it is the most common percentage used for building;
1 / 4, mix of higher quality, it is preferred in the case of expectation of frost;

Lime plasters that can be dated back to Nebuchadnezzar II have been found in Babylon at Ishtar Gate and in the Ninmakh Temple. White plastered walls were found and reported by Koldewey during one of the first excavations at Ninmakh Temple and are well visible in some photos of his reports: *"The temple, like all others hitherto found by us, is composed of mud brick, but we must not judge of its original appearance by the present condition of the ruins; its walls were covered with a white plaster that gave it the appearance of marble"* [4].
In the temple, lime plasters were found, according to Pedersén during an interview with the authors, on the external façade next to the north entrance, on the walls of the courtyard, and in the *cella*. In February 2023, during reparation works, traces of this type of plaster were found also at the base of the external eastern wall (Fig. 3).

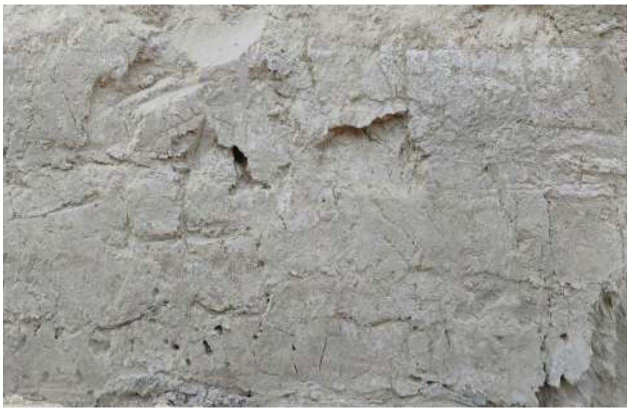

Figure 3: Babylon Ninmakh temple. Lime plaster.

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2. Koldewey 1914, p. 57
3. Langenegger 1911.
4. Koldewey 1914, p. 55

In January 2023, at Ishtar Gate, part of a squared masonry pillar was unearthed during the construction works of the new staircase accessing the site. The pillar is part of the entrance gate to town from the processional way. The fired brick pillar is covered with the same type of lime plaster found at Ninmakh Temple on earthen bricks.

At a preliminary analysis, the plaster, very similar in both cases, appears mixed just with soil and with no pigment added. The result is a pale coating, 1 cm thick in average.
According to these observations, lime plaster has likely been used as finish for the most significative buildings, such as temples and the inner sides of the defensive walls. Further tests on samples of the plaster at the Ishtar Gate have been carried out by ZRS Architekten Ingenieure GmbH in Berlin (Germany) in August 2023, confirming that the composition of the binder of the plaster mortar consists of lime with very low gypsum content. [5]

2.4 INTERPOSITION OF LAYERS OF BITUMEN AND EARTH-BITUMEN MIXES IN MASONRY

The use of bitumen for building purposes dates back to more than 8,000 years ago[6], confirming the highly sophisticated building culture in ancient Mesopotamia. The use of bitumen appears to have been common since prehistoric times and continued in following ages. Bitumen has been regularly used for many purposes, but especially in building practices, as adhesive and protecting bond, and to prevent the infiltration of moisture and water into buildings. It was appreciated due to its broad availability, qualities of impermeability and elasticity, and ease of employ.[7]

Actually, this mineral oil can be found almost everywhere in the country in different forms: liquid, dense or solid. When liquid or dense, it can be used straight to obtain a composite water-resistant mixture, able to stop or at least slow the rise of moisture in the walls. When more solid, it needs to be melted by heating to be brought to a more liquid state. It can then be applied as mortar in between bricks, both fired or not fired, or used, in thin layers, as coating. This is a practice that is often observed in many buildings in Babylon, such as the South Palace, and the Ishtar Gate.

Bitumen was also used as waterproof barrier in between bricks for the construction of rainwater drainage channels, as observed in the Ezida Temple in Borsippa, rebuilt during the new Babylonian era. Although the temple is mostly built with mud bricks, waterways were built with fired bricks laid with a bitumen/soil mix in the form of vertical channels, extending from the top of the roof to the base of the walls (Fig. 5).

Other materials such as lime and soil were sometimes added to bitumen to reduce its fluidity, as found in some ziggurats masonry such as Dorcoricalzo from the middle Babylonian era (c. 1595 – c. 1155 BC), and Borsippa. This type of mix has been used for the construction of walls made both with raw earth and fired bricks.[8] In Borsippa, layers of bitumen mixed with earth or sand have been found in many walls of the ziggurat (Fig. 6). Bitumen layers recur on walls every 5-7 bricks. The bitumen is easily recognizable because of the smell, still very strong and well identifiable. At Ninmakh Temple there are perfectly preserved layers of pure bitumen in between earthen bricks. The better-preserved ones are at the lower part of the wall facing the north entrance (Fig. 7). Here, at a height of 16 cm from the floor, two layers of bitumen about 2 cm thick are placed between earthen bricks. Many other walls built with earthen and fired bricks have been laid with bitumen in Babylon, confirming how common this practice has been through time.

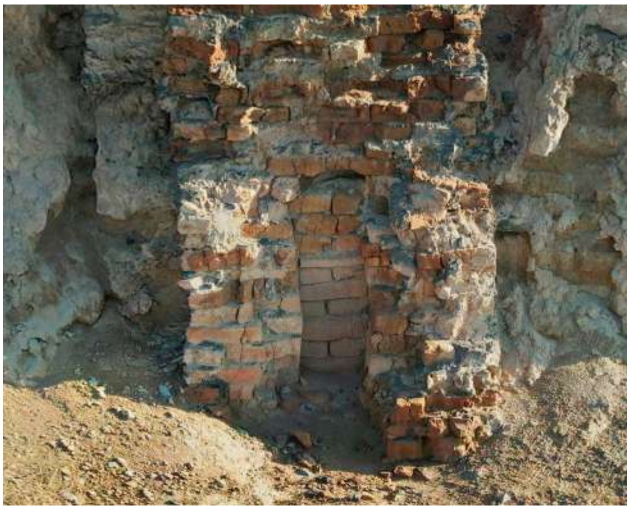

Figure 4: Water drainage in the Ezida Temple.
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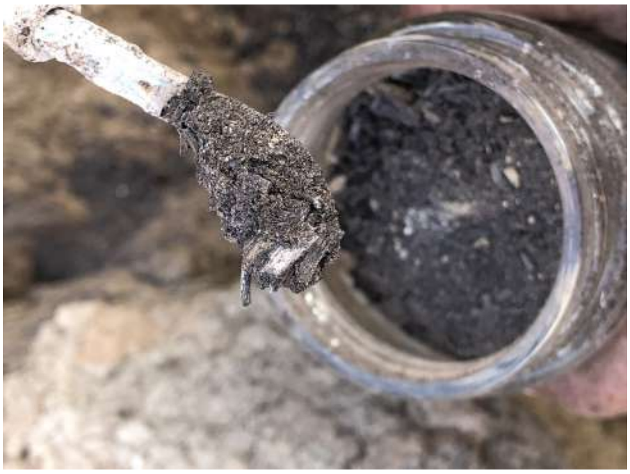

Figure 5: Bitumen mix found in Ezida Temple.
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[5] This information is included in the WMF documentation of the works ongoing at present at Ishtar Gate.

[6] Al-Khatib 2003.

[7] Bahr 1997, p. 170.

[8] Al-Jumaili 1971, p. 70

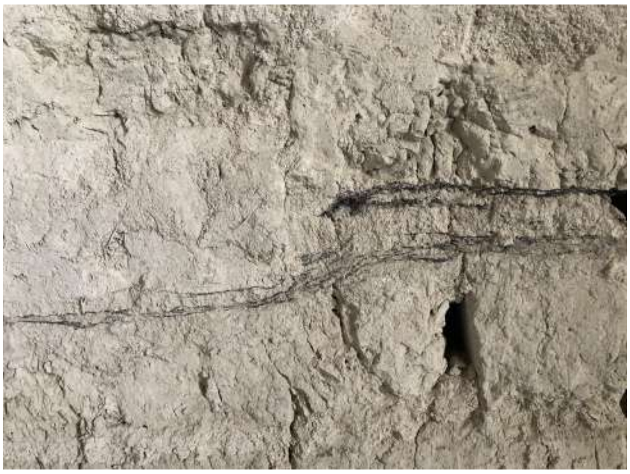

Figure 6: Layers of bitumen in earth masonry at the Ninmakh Temple in Babylon.

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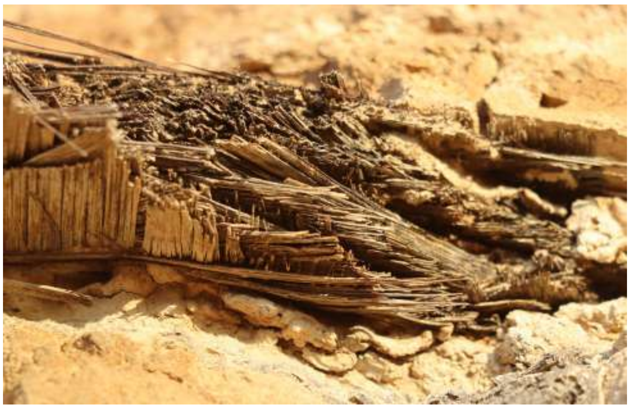

Figure 7: Babylon, bitumen plaster on the South Palace.

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Sometimes fluid bitumen was applied on reed mats. Reed mats, as better explained in the following paragraph, were laid at regular intervals in the earthen masonry. Supposedly, bitumen served as further protection to a system that was evidently used as a barrier for moisture.

Earlier studies[9] concluded that the presence of a high percentage of sulfur in bitumen assures good quality and durability. The bitumen used in Babylon was coming from the city of Hit and its surrounding areas where the percentage of sulfur and bitumen ranges between 7.6 - 9.31% for sulfur and 21 - 28.5% for asphalt. According to both cuneiform texts and Herodotus, the city of Hit was the main center for supplying bitumen to the city of Babylon. Some cuneiform texts refer to Hit also providing the city of Ur with bitumen by transporting it by ship.[10]

2.5 INTERPOSITION OF REED MATS

Reeds are widely spread in Mesopotamia along the Tigris and Euphrates rivers, which provide a perfect environment for these plants. Reeds were easily available to everyone, so the people of Mesopotamia employed them since ancient times for their various daily needs. In the south of Mesopotamia, in the Marshes, they have been used for centuries to build robust houses and furniture.

Earthen houses included reeds as a basic construction material, as a Sumerian proverb indicates[11], "*a lot of building works use bricks, reeds and reed mats, and beams*".

Due to the importance of reeds in the daily life of Mesopotamia, various jobs and specializations emerged related to the harvest and transformation of reeds, employing both men and women.

Reeds were used raw for construction of fences and thin walls, or cut in the form of long strips, which were then weaved by women in form of mats, and then used for different purposes.

Mats were interposed in between earth-brick courses, in one or several layers, most probably depending on the quantity of moisture present, though their purpose might have also been for structural reinforcement. They were interposed at 7-9 brick courses with at times even more as can still be observed at the Summer Palace in Babylon: *"on the north and south-west remains of walls of very considerable height are still standing, with courses of mud brick held together by layers of well-preserved reed stems. They date from a later period and may have belonged to a fort which was erected in Sassanid or Arabic times on the already ruined Babylonian building"*[12] (Figs. 8-9).

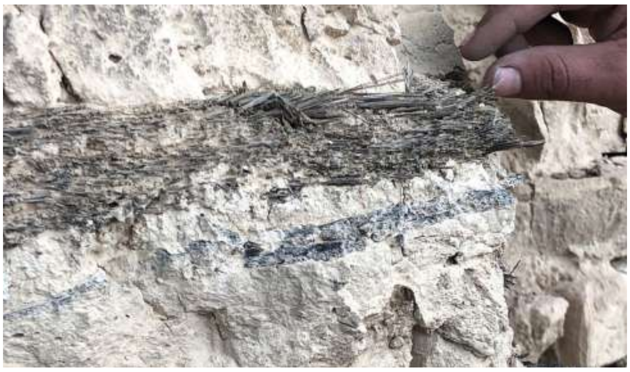

Figure 8: Borsippa: reed mats and bitumen layers in brick masonry.

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Transformed through time, these layers appear now often as a bright white layer. Their presence was reported already by Koldewey in his early excavations: "*After every 9 or 10 layers, a cane or reed mat is inserted into the clay joint to protect the wall from vertical splitting. These inlays of mat, which have deteriorated to a white ash over time, are noticeable throughout the exterior of the walls as white horizontal lines*" (Fig. 10).[13]

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[9] Al-Adhami 1989.

[10] Abdul-Halim 1983.

[11] Al-Shammari 2019.

[12] Koldewey 1914, p. 10

[13] Koldewey 1911, p. 25

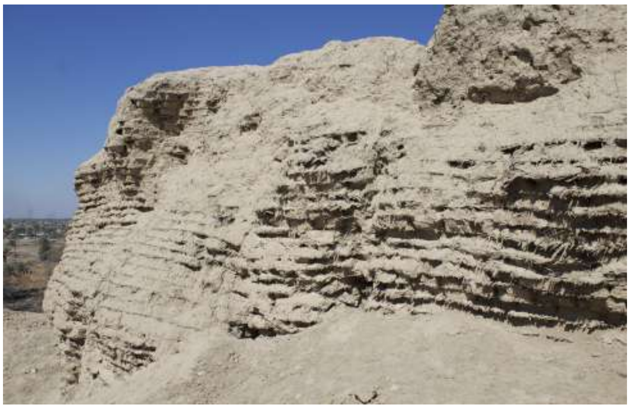

Figure 9: Summer Palace in Babylon.
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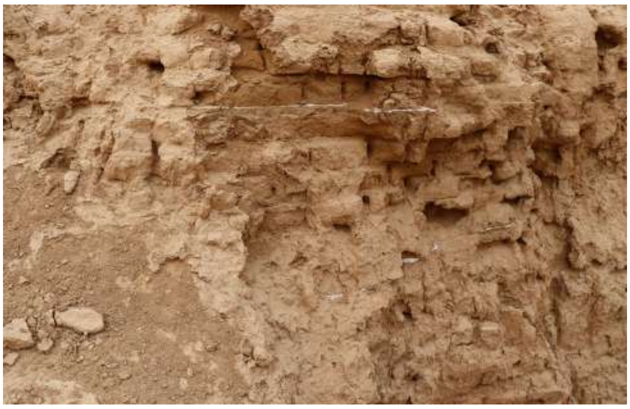

Figure 10: Borsippa: reed mats in earth masonry.
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3. STRATEGIES FOR KEEPING WALLS DRY

3.1 VENTILATION CONDUITS

The remains of the ziggurat in Borsippa show an interesting system of conduits built in the masonry that looks like a well-thought arrangement to provide ventilation and thus, dryness to walls. The whole section of the walls is crossed by 18 x 18 cm straight conduits obtained through a specific bonding pattern. These conduits are positioned at a distance of about 2 m one from each other (Fig. 11).

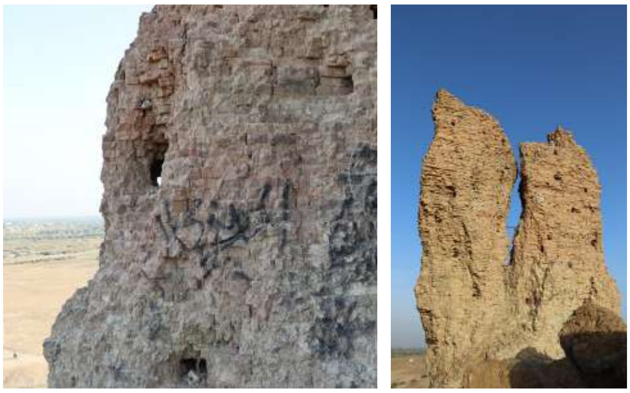

Figure 11: Ventilation channels in brick masonry.
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These conduits are visible in all types of masonry used for the fabrication of the monument, made both with half-baked- and fired bricks, and are not coated on their sides. The direction of the conduits is crossed perpendicularly on the different heights of the walls and goes from one surface to the opposite one across the whole thickness of the walls, in a way that it is easily possible to look through.

W. Allinger Csollich[14] reports a quite detailed description of the fabric of this system, accompanying the design of each layer unearthed. He proposes many hypotheses for the function of these conduits, not coming to a definitive conclusion. Among these hypotheses is the possibility that they could have served as a mean to help the structure dry faster during construction, and to ventilate the core of the building. Something similar was also observed in the ziggurat of Ur where conduits with a similar pattern were also considered as ventilator ducts. Even though little literature was found by the authors on this subject, and apparently no in-depth investigation has been undertaken recently on this topic so far, it remains difficult to attribute to these conduits a different function than ventilation, given that the ziggurat is a massively built object, with no rooms or empty spaces inside.

It will be therefore convenient that deeper survey and further research be made to survey these particular construction practices and to better understand their function.

3.2 BITUMEN PLASTERS, FLOORS AND ROOFS

Fired brick walls were sometimes waterproofed with bitumen if exposed to weathering, as in open courtyards, or if in direct contact with water, such as for gutter canals[15]. Some bitumen plasters are still visible in many buildings, such as is the North Palace in Babylon. Here, a layer of this building material is observed, 1-2 cm thick.

Floors were also commonly covered with bitumen as described in Koldewey's report: "*Between them (two walls, editor's note) is a broad street or roadway, which leads directly to the Ishtar Gate, made by Nebuchadnezzar as a processional road for the God Marduk, to whose temple of Esagila it eventually leads. It still possesses the brick pavement covered with asphalt which formed a substratum for the immense flagged pavement*" and again about the Ninmakh temple with the following: "*The floor of the courtyard and of the rooms was laid on asphalt and covered with asphalt too*". [16]

The protection of the roof from the permeation of moisture was assured by a layer of reeds and asphalt placed over a strong wooden roofing and, above this, rested two courses of bricks

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14. Allinger-csollich 1991.
15. Al-Adhami 1989.
16. Koldewey 1911, pp. 4-6

laid in mortar.[17] As described by old masons interviewed, a layer of soil is placed on on top structural elements, making it possible to plant barley. This practice has been used traditionally in the Babil region until some decades ago. According to the same people interviewed, the barley roots help to consolidate the soil layer and absorb all the water brought by rains. It is a fascinating practice, that brings the thought back to the famous Babylonian hanging gardens.

CONCLUSIONS

This contribution describes the first results of a general analysis of the archaeological sites of the Babil region, focusing on the strategies of ancient builders to protect monuments and civil buildings from the aggression of capillary rise and pathologies caused by the action of rain. All descriptions are the result of research at a very initial stage, not supported by scientific test analysis as those have not yet been authorized. Nevertheless, a recurrent practice can be observed of using certain materials in a repeated manner, confirmed by literature produced by archaeologists in the early years of the XXth century.

The skilled use of different materials and technologies to address the presence of moisture and water in buildings has led to the development of creative strategies to contain, when not eliminate the problem.

Lime, bitumen, and reed mats have been used alone or combined to assure the best result for waterproof walls and external surfaces. Their excellent quality has survived through centuries and today represent a very inspiring testimony of an ancient, sophisticated building culture.

Amazing technologies such as the channels of the ziggurat in Borsippa and the roofs planted with barley deserve consideration and scientific in-depth studies to verify their real function and eventually allow us to achieve new useful knowledge for our future practice.

What was observed until now has just opened the path to broader research on building practices and construction skills that just confirm, if ever necessary, why Iraqi architecture has been kept with such high consideration throughout history.

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[17] Koldewey 1911, p. 26

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THEMATIC WORKSHOPS

ÉLÉMENTERRE PEDAGOGICAL KIT

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ÉLÉMENTERRE is a pedagogical toolkit developed by CRAterre to introduce architecture and engineering students, construction professionals, as well as schoolchildren and the general public to the properties of earthen materials and to understand why and how it is possible to build with earth.

The workshop enabled conference participants to carry out simple scientific experiments of this toolkit, offering tactile, playful, surprising or spectacular relationship with soil and its components: grains – pebbles, gravel, sand and clay – water and air. By combining them, one can obtain a solid material which makes it possible to construct buildings and homes capable of withstanding for centuries, even millennia, as well showcased along the Nile Valley.

ÉLÉMENTERRE was developed by ethnologist Nathalie Sabatier and architect Alba Rivero. It was presented at the Nile's Earth Conference by Liz Karin Enciso Benitez.

For more info:
https://craterre.hypotheses.org/3187

FIELD TESTS FOR CONSERVATION WORK

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The workshop “Field tests for conservation work” aimed at providing an understanding of how samples of adobe bricks made from soils available in a specific area can be tested to compare their mechanical and behavioral properties in the face of the potential deterioration processes most commonly found at different archaeological sites.

To properly illustrate the variety of properties that can be obtained, two different soils were used, one with a high clay composition and the other with a high sand composition. The mixes were prepared with different ratios of the components, some adding bio-sourced material (straw) or stabilizing them with mineral binders (hydraulic lime and Portland cement).

The four tests demonstrated by Arch. Roy Aghnatios (DSA Terre at ENSAG) aimed to simulate potential threats to the durability of mud bricks :

a. The capillarity test demonstrates the capillary rise found in an archaeological site, giving an insight on the capacity of mud bricks to withstand in a humid environment.

b. The erosion test reveals the potential durability of bricks in the face of natural aging when exposed to heavy rain or storms.

c. The abrasion test helps determines the solidity of the surface in the face of sand, wind and sometimes human movement.

d. The tensile strength test gives an idea of the ability of bricks to withstand heavy weighs.

BIOGRAPHIES

Doukki Gel archaeological site, Kerma, Sudan © Mission Kerma-Doukki Gel/B.-N. Chagny

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AHMED HUSSEIN ABDELRAHMAN ADAM
is Associate Professor in the Department of Archaeology at the University of Khartoum, Sudan. He is currently a visiting researcher at the Faculty of Communication, Culture and Society, Università della Svizzera Italiana, Lugano. Former Head of the Department of Archaeology, former Head of the Directorate and former Head of the Directorate of University Museums at the University of Khartoum, he has also directed several major field projects: Director of the Red Sea and Suakin project for archaeological, cultural and environmental studies, co-director with Dr. Michael Brass (Institute of Archaeology, University College London) of the UCL - UofK expedition south of Gezira (Sudan): Mobility, identity and the interaction of pastoral peoples with the Nile Valley, and project director of the historic city of Khandaq in northern Sudan.

AHMED ALTAHER
is co-director of the CFEETK, co-director of Karnak origin and Ramses III gate at Karnak. Director of khonsu and Montu Temples graffiti project. Site supervisor of Egyptian-Chinese joint mission in Montu Temple at Karnak, a site supervisor of South Abydos Excavations Early Dynastic Cemetery and Settlement, a team member of front of Karnak Temple excavation and excavation supervisor of different field school around Upper Egypt; he a sectors supervisor of the Sphinx Avenue excavation since 2010.

AMMAR AL TAEE
Archaeologist, MA in Sumerology, Researcher in archaeology, works at Inspectorate of Antiquities and Heritage of Babylon, Department of Archaeological Buildings Maintenance, SBAH - Iraqi State Board of Antiquities and Heritage (Iraq).

AZEDDINE BELAKEHAL
His academic career has been firstly focused on climatic and energetic parameters involved in the urban and architectural design process and presenting a conflict with design qualitative factors, particularly aesthetics and users' both perception and behaviour. Ambiences in both contemporary buildings and architectural heritage constitute the extended field of his research work associating environmental factors, sensorial human aspects, building shape and occupancy.

HAROUNE BEN CHARIF
is currently a PhD candidate at the University of Campania "Luigi Vanvitelli," with a focus on documentation techniques of earthen-built heritage. As an architect, Haroune dedicated almost 4 years with the CAPTERRE team, working on numerous projects aimed at promoting the use of earthen materials and preserving earthen architecture. He holds an MA in Architecture from Université de Biskra and a second MA in Social Development from both universities; ELTE of Budapest and the University of Catania in Sicily.

ZINEB BENNOUNA
is a 26-year-old Ph.D. candidate in Architecture and Heritage studies at the University of Paris Diderot and the ENSAPVS. She grew up in Morocco where she learned to see architecture through the prism of history and the vernacular. She strongly believes in the efficiency of traditional devices in contemporary architecture. The main purpose of her research is to free the Mashrabiyya from all stereotypes and misinterpretations that the Orientalism movement has anchored in the minds. Her work also aims to prove that intimacy is not opposed to hospitality. She truly hopes that one day, the Mashrabiyya will not be veiled anymore by other "concepts" and will be adequately referred to on the architectural scene.

KRZYSZTOF CHMIELEWSKI
is a conservator of paintings and art historian. Head of the Department of Conservation and Restoration of Panel Painting and Polychrome Sculptures and Inter-Chair Studio of Conservation and Restoration of Archaeological and Ethnographic Heritage (Academy of Fine Arts in Warsaw). Experienced in directing conservation works on archaeological sites in Lebanon, Libya, Syria, Sudan and Italy.

MAËL CRÉPY
is a geographer specialising in human-environments interactions in arid areas. He is scientific member of the Ifao, associate researcher at the Archéorient and member of several archaeological missions, including the French mission at Taposiris-Plinthine in which he carries out research into resource exploitation, including soil exploitation for mudbrick preparation.

ANTHONY (TONY) CROSBY
is a preservation architect with over 50 years of experience working in the field of earthen architecture preservation and the past 24 years on various projects in the Nile Valley. In 2012 he was designated as one of five "Founders" of earth architecture preservation by the International Scientific Committee of Earthen Architecture Heritage (ISCEAH), ICOMOS.

AYMAN MOHAMED DAMARANY
is an Antiquities Inspector in Abydos and founder and co-director of the Abydos Archive Project. He has a background in archaeology, having earned his bachelor's at Souhag University, and is currently attending graduate school at Cairo University. He spe-

cializes in physical anthropology and archaeological photography, and was the staff photographer at the American Research Center Egypt between 2014-2018. He has directed numerous archaeological projects in Upper Egypt for the Ministry of Antiquities, and is also a team member and photographer with several foreign missions in Abydos and Luxor.

SYLVAIN DHENNIN

is researcher at the CNRS (Lyon, UMR 5189 HiSoMA) and an egyptologist archaeologist. A former scientific member of the IFAO (Cairo), he excavates in the Plinthine site, is responsible for the excavation of the Dendera animal necropolis and supervises the excavations of the Kom Abu Billu site.

YUJIA FAN

is a doctoral candidate at the School of Architecture and Urban Planning, Beijing University of Civil Engineering and Architecture, Beijing, China.

SHAIMAA FOUAD ELSHISHTAWY

has extensive academic and professional experience in archaeology and conservation of earthen architecture. Currently, she is working at the technical office of assistant Minister of the project of monuments and museums and head of the restoration and projects of the monuments and museums in Egypt.

TOMOMI FUSHIYA

is Assistant Professor at the Polish Centre of Mediterranean Archaeology, University of Warsaw, and is in charge of developing collaborative archaeological programmes. Specialising in heritage management planning, collaborative archaeology, and engagement programme design, she has worked in Sudan, Egypt, and Cyprus.

MARTYNA GREGORIOU-SZCZEPANIAK

is assistant in the Department of Fundamentals of Buildings within the Institute of Building Engineering at the Faculty of Civil Engineering of Warsaw University of Technology. Her professional work is dedicated to the diagnostics of existing buildings, especially the analysis of the load-bearing capacity of ancient masonry structures.

MOHAMMED HASSAN SIEDAHMED

is the Director of Information & Promotion Directorate at the Supreme Council of Tourism and Antiquities of the Northern State in Dongola, Sudan, and a lecturer at University of Dongola. He is an engagement facilitator and research collaborator with the Old Dongola project of the Polish Centre of Mediterranean Archaeology, University of Warsaw.

XAVIER HÉNAFF

is a professional archaeologist at Inrap, in charge of excavation and diagnostic operations. In 2009, he joined the Franco-Swiss Archaeological Mission of Saqqâra under the direction of P. Collombert, participating in this mission as an archaeologist and ceramologist.

KAREL INNEMÉE

He studied History of art and Archaeology and received his PhD at Leiden University. He specialised in the Christian culture of the Near East and is currently an assistant professor at the University of Warsaw, where he is part of the team that excavates and conserves the church at Miseeda.

THIERRY JOFFROY

is an architect. After a long career working in the field, he is now the Director of the CRAterre research team and directing PHD students. In 2010, his work in the field of conservation was recognized with the silver medal of the French Academy of Architecture.

HENK JONKERS

He received his PhD degree from Groningen University in 1999. He is currently a full professor leading the Sustainability research group within the Materials & Environment section of the Materials, Mechanics, Management and Design (3MD) department at the CEG Faculty of the Delft University of Technology. His main research concerns development of low environmental footprint but high performance bio-adapted, self-healing, and circular construction materials.

DOLORES JOYANES-DÍAZ

is Senior Professor at Higher Technical School of Architecture, University of Malaga. Lecturer in Architectural Graphic Expressión, Drawing and Descriptive Geometry area. Principal researcher in project UMA20-FEDERJA-075.: Archaelogy, Architecture and Landscape: typological evolution and state of conservation of the tombs in the necropolis of Qubbet el Hawa (Aswan, Egypt). Specializing in Landscape, heritage and egyptology.

NATHALIE KAYSER-LIENHARD

Academic Research Engineer (civil servant), she is in charge of the library and documentary collection on ancient Egypt at Sorbonne University. She ensures the conservation, development and valorization of the collections of the Egyptological Research Centre of the Sorbonne (CRES).

SAYED MOSSADEQ KHALILI

is an architect and architectural historian from Afghanistan. After working for 14 years in the fields of Culture, Cultural Heritage Preservation, and Diplomacy in the Former Afghanistan Government, he is currently a political refugee in France and works as a Post-Doc Researcher With CRATerre-ENSAG in the framework of the PAUSE program.

JAROMÍR KREJČÍ

is an Egyptologist with archaeological experience in Egypt (Abusir Centre) since 1991. He specializes in Egyptian archaeology and history (during the period of the end of the 4th to the middle of the 2nd millennium BC), the development of monumental Egyptian architecture, the sun cult and its manifestations and possibilities for the restoration of archaeological monuments.

YASK KULSHRESHTHA
He received his Ph.D at the Faculty of Civil Engineering and Geosciences. He is carrying out multidisciplinary research in the section of Materials & Environment (CiTG), Geo-Engineering (CitG), Architecture (BK) and Environmental Biotechnology (AS). His research focuses on Building affordable and durable earthen houses using local bio-resources.

FIKRIYE PELIN KURTUL-VACEK
As an architect, she specializes in building biology studies and earthen building materials. In addition to her role as a project designer, she has served as a local consultant for UN-Habitat and taught at several educational institutions. Currently, she is employed as a scientific researcher at the Center for Architectural Heritage and Infrastructure at UWK. Her doctoral research is continuing at the TUWien.

PETER LACOVARA
is director of the Ancient Egyptian Heritage and Archaeology Fund and previously was curator at the Michael C. Carlos Museum and Museum of Fine Arts, Boston. Currently, he is directing the work at the site of Deir el-Ballas and has excavated at the sites of Malqata, The Valley of the Kings, Abydos, Gebel Silsileh, Giza and Hierakonpolis. He has also taught at Syracuse University, The American University in Cairo, The Massachusetts Institute of Technology, and elsewhere. He has written on settlement patterns, mortuary traditions, and the material culture of ancient Egypt and Nubia.

CARMEN MUÑOZ-GONZÁLEZ
is Senior Professor at Higher Technical School of Architecture, University of Malaga. Lecturer in Construction Area. Researcher in project UMA20-FEDERJA-075: Archaelogy, Architecture and Landscape: typological evolution and state of conservation of the tombs in the necropolis of Qubbet el Hawa (Aswan, Egypt). Specializing in Architecture, Heritage, Environmental Conditioning, Preservation and Climate Change.

CORTEN PÉREZ-HOUIS
He started a PhD thesis in Geography in 2020, under the supervision of Eric Denis (Géographie-Cités) and Alice Franck (Prodig). He studies the red brick supply chains in Cairo and Khartoum, from the production of this building material to its use in the contemporary construction of the two capitals.

JENNIFFER QUIROZ BRAVO
is architect by the University of Valparaíso, Chile. Candidate to Master in Architecture and Historical Heritage by the University of Seville, Spain. Since 2010 working in architectural restoration and cultural heritage intervention. Researcher in areas of vernacular built heritage and architectural and cultural heritage. Currently associate researcher at the Regional Museum of Iquique, Chile.

BÉRANGÈRE REDON
Former scientific member of the IFAO from 2009 to 2012, she is an historian and archaeologist specialised in the study of the foreign presences (Greek and Roman) on the fringes of Egypt. She has been working within the French mission at Taposiris-Plinthine since 2002 and took over the directorship of this mission from M.-Fr. Boussac in 2018.

MAGDALENA SKARŻYŃSKA
is a conservator of paintings and art historian, specialised in wall paintings and ceramics conservation. Chief conservator at PCMA University of Warsaw, supervising conservation activities within the framework of conservation projects on archaeological sites. She has participated in projects in Romania, Peru, Italy, Georgia, Egypt, Sudan, Cyprus, Ukraine and Poland.

EWA SOBCZYŃSKA
is assistant in the Department of Fundamentals of Buildings within the Institute of Building Engineering at the Faculty of Civil Engineering of Warsaw University of Technology. Her professional work is dedicated to structural design and diagnostics of existing buildings.

SYLWIA SVOROVÁ PAWEŁKOWICZ
is graduated from the Faculty of Conservation and Restoration (Warsaw Academy of Fine Arts). Since 2010 she has worked on various research projects concerning monuments located in Poland, Ukraine, Egypt, and Sudan. She is currently working at the Department of Lime Technologies, Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences. Her research interests focus on pigment identification, and the use of optical and electron microscopy in heritage studies.

OLGA SYTA
is a graduate of the Inter-Faculty Individual Studies in Mathematics and Natural Sciences (2012) and the Center for Latin American Studies at the University of Warsaw (2014). Obtained a PhD degree in chemical sciences in 2019 at the same university. Her scientific interest concerns the use of physicochemical methods in the analysis of historic and archaeological objects.

WOJCIECH TERLIKOWSKI
is assistant professor in the Department of Fundamentals of Buildings within the Institute of Building Engineering at the Faculty of Civil Engineering of Warsaw University of Technology. His professional work is dedicated to structural design and assessment including diagnostics and refurbishment of structures.

MATTHIEU VANPEENE
Graduated from the École Nationale d'Architecture de Paris Belleville (ENSAPB) and the École Pratique des Hautes Études (EPHE, PSL), he runs the architecture and archaeology department of the Centre Franco-Égyptien d'Étude des Temples de Karnak (CFEETK, CNRS UAR 3172). He is also part of several missions of the Institut Français d'Archéologie Orientale (IFAO) in Egypt including Dendara, where he works since 2014.

CLÉMENT VENTON
is an architect who worked in the United Arab Emirates and Saudi Arabia on the architectural and urban study and conservation of earthen heritage sites from 2019 to 2020. He has been working with the French mission at Taposiris-Plinthine since 2022, he graduated the same year from a specialisation diploma in earthen architecture under the direction of the CRAterre laboratory.

KACPER WASILEWSKI
is structural engineer and researcher in the Department of Fundamentals of Building within the Institute of Building Engineering at the Faculty of Civil Engineering of Warsaw University of Technology. Experienced in the field of assessment of historic structures as well as plans for their strengthening and reconstruction.

DOBROCHNA ZIELIŃSKA
is an archaeologist studying cultures of Late Antique and Medieval Nubia. She has graduated from the Faculty of Archaeology, University of Warsaw, where she works as an assistant professor, currently directing the project concerning the research and conservation of the church at Miseeda.

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CONFERENCE COMMITTEES

ORGANISATION COMMITTEE

The Nile's Earth international conference was organised by the École Nationale Supérieure d'Architecture de Grenoble (ENSAG-UGA) in collaboration with the UMR 5189 Histoire et Sources des Mondes Antiques (CNRS), the International Centre for Earthen Construction (CRAterre), the French Institute of Oriental Archaeology in Cairo (Ifao), the Centre Franco-Égyptien d'Étude des Temples de Karnak (CFEETK, CNRS/MoTA), and the Section Française de la Direction des Antiquités du Soudan (SFDAS).

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ANITA QUILES
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MADDALENA ACHENZA
Professor, Cagliari University

JULIE ANDERSON
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NINON BLOND
Lecturer, École Normale Supérieure de Lyon

PR. CHARLES BONNET
Member of the Académie des Inscriptions et Belles Lettres

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MANAL ABDEL MONEIM GHANNAM
holds a master's degree in conservation of mural drawings in ancient Islamic buildings since 2002, and a PhD since 2008 in conservation of antiquities in the use of alternative supports in the displaying of detached mural drawings in cooperation with the Sapienza University in Rome, Italy. She served as Deputy Secretary-General of the Supreme Council of Antiquities for Conservation and Restoration Affairs (2021), General Director of the Center for Restoration and Conservation of Antiquities at the National Museum of Egyptian Civilization (NMEC) (2018 – 2021), General Director of the Restoration Department of the Manial Palace Museum (2012 – 2018) and Director of the Technical Office and Restoration Projects of CACRAM (2006 – 2010). She has been supervising many foreign missions and archaeological sites in Egypt, as well as the restoration and conservation of the royal mummies, packing them and transferring them to the National Museum of Egyptian Civilization (NMEC). Since 2021, she is Head of the Central Administration for the Conservation and Restoration of Antiquities and Museums (CACRAM).

ABDELHAI ABDELSAWI FEDLELMULA
graduated in geology from the Faculty of Science, University of Khartoum, and holds a master's degree in geoarchaeology (Origin of sediments at Kadero Neolithic site), 1998-2001-Poznan-Poland. After initial experience with the Roots drilling company, in 1989 he became Inspector of Antiquities at NCAM (National Corporation for Antiquities and Museums). He has led several excavations in Sudan as field director for several projects: Merwe Dam Archaeological Salvage Project (MADAP, 2001-2004), Roseris Dam heightening Salvage Project (ROS, 2010-2012), Upper Atbara -Setit Dam Archaeological Salvage Project (UA, 2013), Deba-Dam Archaeological Survey Project (DDASP qutari project, 2013-2014). He is currently researching in Blue Nile Archaeology as part of a PhD and is Head of the Archaeology department at NCAM.

MADDALENA ACHENZA
architect, holds a degree in architecture from the University of Florence, a PhD in architecture obtained in Cagliari and the CEEA-Terre (Certificat d'Etudes Approfondies en Architecture) achieved at CRATerre - ENSAG in Grenoble (France). She is an associate professor at the University of Cagliari, Faculty of Civil, Environmental and Architecture Engineering, where she also teaches courses in the frame of the UNESCO Chair «Earthen architecture, building cultures and sustainable development». President of ICOMOS-ISCEAH International Scientific Committee for earthen architectural heritage and coordinator of the same committee within ICOMOS Italy. She is technical consultant for the International Association of Earthen Cities (Italy), and World Monuments Fund (USA). She is a member of scientific and organizational committees of numerous international conferences and of the latest World Terra Congresses. She has participated as manager, coordinator or partner in various international projects financed by the European Community and the Autonomous Region of Sardinia on the themes of conservation and enhancement of the vernacular heritage, and in particular the heritage built with earth. She has a long and intense experience of teaching at academic level and for professional training in the field of vernacular and sustainable architecture. Achenza is author of over 80 publications.

JULIE ANDERSON
is Curator for Sudan and Nubia in the Department of Egypt and Sudan at the British Museum. Receiving her PhD from the University of Toronto, Canada in 1996, her thesis focused on domestic and civil architecture in medieval Sudan. She has worked extensively in Sudan and Egypt for over 30 years excavating numerous sites and has co-directed the Sudan National Corporation for Antiquities and Museums' Berber-Abidiya Archaeological Project since 1997. Entitled Finding Sustainability in the Desert, the ongoing conservation work by the project of the monumental 1st century AD Amun temple at Dangeil, Sudan was selected by the International Institute for Conservation of Historic and Artistic Works (IIC) as part of their contribution to the UN Climate Change Conference UK 2021 (COP26) held in Glasgow. The project has also been short-listed for the ICCROM-Sharjah Award for Good Practices in Cultural Heritage Conservation and Management in the Arab Region, 2019 – First Category, Heritage Sites and Buildings. Currently she is Honorary Chair of the Sudan Archaeological Research Society, Honorary Secretary for the International Society for Nubian Studies, and Editor of Sudan & Nubia.

NINON BLOND
is a PhD in geography from the University of Lyon and an Assistant Professor at the ENS of Lyon. As a geographer working on Holocene socio-environmental interactions in Africa (Ethiopia, Sudan, Egypt, Tunisia) and the Middle East (Iraq), her work is based on a systemic, integrated, multi-method and resolutely interdisciplinary approach, at the interface between geography, geomorphology, geoarchaeology, sedimentology, geohistory and ethno-geomorphology. Her research issues allow her to understand the mutations of socioecosystems and the relationships between societies and their environments at different spatial and temporal scales. In East Africa, she works mainly on climatic and environmental evolutions of the northern Nile basin, where she seeks to identify the biophysical and/or anthropogenic, socio-political or cultural factors at the origin of the evolutions in the relationships between societies and environments. Within the Nile's Earth project, she works in particular on the relations of ancient and contemporary populations to the river, in a tension between risk and resource - the resource being here the earth that allows the construction of buildings or the manufacture of objects. She combines geomorphological surveys, the study of sedimentary deposits and interviews on the sites of Kerma-Doukki Gel (Sudan), Medamud and Karnak-Treasury of Shabaqo (Egypt).

PR. CHARLES BONNET
is an archaeologist, medievalist and specialist of Ancient Nubia. After obtaining a degree in agriculture, he studied Egyptology from 1961 to 1965 at the Centre d'études orientales of the Uni-

versity of Geneva. In 1975, he obtained his PhD degree in Medieval archaeology (University of Lyon II). Between 1982 and 1992, he was an advisor to the Fonds national suisse de la Recherche scientifique and an expert in the research program "Conservation methods for cultural heritage". In 1975, he became director of the Swiss mission in Kerma, then co-director of the joint Swiss-French-Sudanese mission in Kerma-Dukki Gel between 2013 and 2022. He became a visiting professor at the Collège de France in 1985 and was elected Correspondant étranger to the Académie des Inscriptions et Belles-Lettres in 1990. During his career, he has directed numerous archaeological excavations in Switzerland, Italy, France, Jordan, Egypt and Sudan.

DR. ANN BOURGÈS

is a conservation scientist at C2RMF (HDR in 2017 in materials science). In 2006 she obtained her PhD in mineralogy at the University of Geosciences at the Ludwig-Maximilians-Universität in Munich. She worked as a conservation scientist specializing in stone and clay conservation at the Laboratoire de Recherche des Monuments historiques (LRMH) for 13 years and now holds the same position at the Centre de Recherche et de Restauration des Musées de France (C2RMF). Ann Bourgès is secretary general of ICOMOS France and leads the climate and heritage working group as well as the WP6 Climate, interface and Patrimoine of the national research project Equipex+ Espadon. She also leads the AFNOR group on the standardization of cultural goods - inorganic porous materials constituting cultural heritage.

MAËL CRÉPY

is a geographer and geoarchaeologist, specialist in the interactions between societies and arid or semi-arid environments in the late Holocene. After a PhD on the oases of the Kharga Depression in the Western Desert of Egypt, he contributed to several archaeological and geoarchaeological projects in Tunisia, the United Arab Emirates, Uzbekistan and Egypt. He mobilises methods of physical geography, spatial analysis and the study of Western travelers' accounts (18th-20th c.) in order to assess the ways in which humans transformed their environments, in particular through the exploitation of water, soil and natural resources. After consolidating his approaches and methodology by applying them to a vast portion of the Egyptian territory within the framework of the Desert Networks project (dir. B. Redon, https://desertnetworks.huma-num.fr/), he joined the Institut français d'archéologie orientale (Egypt, https://www.ifao.egnet.net/) in September 2021 as a scientific member. He is developing research on the socio-environmental evolution of the desert margins of Egypt from the beginning of the Old Egyptian Empire to the present day. He participates in six archaeological missions (one in Uzbekistan and five in Egypt), including the Mission Archéologique Française du Désert Oriental (MAFDO), for which he is taking over the direction this year (https://desorient.hypotheses.org/).

TONY CROSBY

is a Preservation Architect for 50 years which includes 25 years with the US National Park Service working throughout the US on preservation projects. He left the NPS in 1998 and continued in private practice, working both nationally and internationally. Projects include the development of a national assessment of heritage protection needs in Armenia, condition assessments, historic structure reports and conservation intervention directives and specifications for historic structures, such as Mission San Miguel and the Royal Presidio Chapel in California, historic site of Atturaif in Saudi Arabia, and numerous mud brick sites in Egypt. He also has worked at archeological sites in the United States, in Central and South America, including planning for heritage and hands on preservation work. Experience also includes documentation and preservation design for earthen archeological sites, construction documents for historic structures, development of preservation maintenance programs, project management and field supervision of preservation projects. He has written on preservation in National and International publications and taught at local, regional, national, and international preservation meetings and courses. Currently serving on the Board of ISCEAH, the International Scientific Committee on Earthen Architecture Heritage, ICOMOS as an expert member.

ISLAM MOHAMED EZZAT

is an assistant lecturer, Department of Museums and Sites Management, Faculty of Archaeology, Ainshams University. Researcher of ancient materials studies and restoration of antiquities, The Archaeometry Department, the French Institute for Oriental Archaeology (Ifao). He used to be the Egyptian government coordinator of the EU-funded project "Transforming the Egyptian museum Cairo". Graduated from the Conservation of Antiquities Department, Faculty of Archaeology, Cairo University in 2010. He obtained the master's degree in the strategic management of museums and cultural heritage organizations from the National School of Public Administration and Scientific Research, Quebec University, Canada in September 2019. He obtained another master's degree in applications of Nanotechnology in conservation of organic artefacts, from the Faculty of Archaeology, Cairo University. He received various scholarships and training courses in Conservation sciences, Museology and Archaeometry in Germany, the United Kingdom and Austria. He gained the prize of excellence of research from the National Institute of Public Management of Canada, considering his master's thesis as one of the best five theses in the Canadian federal universities in 2020.

PR. FEKRI HASSAN

is Director of the Cultural Heritage Program at the French University in Egypt. He is Emeritus Petrie Professor of Archaeology at the Institute of Archaeology, University College London. He has a Ph.D. in Anthropology, Southern Methodist University (1973). He served as Vice-President of "World Archaeology Congress", and President of the "Water History Association", and served as chief editor of "African Archaeological Review" for 10 years. Hassan has a long career in archaeology, geoarchaeology, demographic archaeology, water history and cultural heritage management with more than 300 publications and reports. He led many archaeological field expeditions since 1974 in search for archaeological indications for the origins of agriculture and state society in Egypt. In combination with his main interest in archaeology, Hassan's contributions extend to the role of urban centers and cities in Egypt and elsewhere. His interest in urban archaeology is conjoined with his involvement in the preservation and management of urban heritage. This led him to become concerned with the problems facing the valorization of Hassan Fathy's legacy in Egypt and the demise of his village in New Gourna, which culminated in the restoration of one of the remaining houses as a center for Hassan Fathy's architecture and sustainable development.

DAVID GANDREAU

is an archaeologist, PhD in architecture, researcher at the National School of Architecture of Grenoble (ENSAG/UGA). He is specialized in earthen cultural heritage studies, conservation and valorization. He has carried out numerous missions of expertise and training, in particular on World Heritage sites in the Middle East and in Africa. Since 2018, He is co-responsible for the UNESCO Chair "Earthen Architecture, Constructive Cultures and Sustainable Development".

THIERRY JOFFROY

is an architect and researcher at Grenoble National School of Architecture, expert in earthen architecture and local building cultures. Since 1986 he has participated in the teachings of the post master on earthen architecture (DSA Terre) before taking the responsibility of its coordination and since 2009, its scientific direction. In the meantime, he has been participating in various research work of the CRAterre research Laboratory with being active in many fields (more than 300 missions carried out in 60 countries) through providing his expertise for the elaboration and implementation of various projects and programs I the fields of architecture, heritage and sustainable development, including the AFRICA 2009 program. In 2010, the Academy of Architecture awarded him the "restoration" silver medal in recognition of his numerous works on the conservation of heritage in connection with ICCROM and the UNESCO World Heritage Center. Since 2011, he has assumed the scientific responsibility of the AE&CC Laboratory of Excellence (Labex), which now includes more than 100 researchers in architecture, town planning and territorial sciences. In 2018 he has been empowered to direct researches (HDR) and now supervises several theses in architecture.

NADIA LICITRA

is an archaeologist, post-doc fellow of CRAterre (AE&CC/ENSAG/UGA) and associated member of UMR 8167 Orient&Méditerranée of CNRS. She obtained her PhD degree in Egyptology in 2014 (Paris-Sorbonne University) and since 2008 she has been the Director of the archaeological mission at the Treasury of Shabaqo in Karnak (UMR 8167/CFEETK). She has taken part in several archaeological missions in Italy, Egypt and Sudan. Her research focuses mainly on storage architecture, construction techniques and materials of Nile valley earthen architecture.

SÉVERINE MARCHI

is an archaeologist attached to the CNRS' research unit UMR 8167-Orient et Méditerranée. Since 1998, she is involved in several missions in Egypt (Tell el-Herr, Ouadi el-Jarf, Taposiris-Plinthine, Treasure of Chabaka at Karnak) and Sudan (Gism el-Arba, Zankor-Abou Sofyan, Kerma-Dukki Gel). She is co-director of the Swiss-French-Sudanese archaeological mission of Kerma-Doukki Gel. Her research topics and current projects mainly concern urban archaeology, domestic and military architecture and the study of related archaeological material. She also contributes to several programmes on storage facilities, archaeometallurgy and faience crafts in the Nile Valley.

ANITA QUILES

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BÉRANGÈRE REDON

is a historian and archaeologist, specializing in foreign presences (Greek and Roman) in the areas located on the fringes of Egypt. She is a research fellow at the CNRS (HiSoMA, Lyon) since 2012. B. Redon currently leads the ERC project "Desert Networks: Into the Eastern Desert of Egypt from the New Kingdom to the Roman period" (ERC-2017-STG, proposal number 759078). In this project, she is reconstructing the circulation networks in the Eastern Desert of Egypt. In parallel, Bérangère Redon is the director of the French mission of Taposiris-Plinthine, on the Mediterranean coast, in the Alexandrian region. She began in 2013 the exploration of the site of Kom el-Nogous, which probably hosts the remains of the locality of Plinthine, cited by Herodotus. This work, conducted by a multidisciplinary team, gathering archaeologists, Egyptologists, ceramologists, archaeobotanists, geographers and architects, has revealed the dynamism of the locality from the New Kingdom (mid-2nd millennium BCE) to the early Roman period. A temple of Rameses II is being excavated, and the site is most probably the heart of a vineyard created by the pharaonic power to exploit and secure the northwestern margin of Egypt.

CORINNA ROSSI

is an Italian Egyptologist. She graduated in Architecture at the Università degli Studi di Napoli Federico II and specialized in Egyptology with an M.Phil. and a Ph.D at Cambridge University (UK) under the supervision of Barry J. Kemp. She was Junior Research Fellow at Churchill College (Cambridge, UK) and later became Associate Professor of Egyptology at Politecnico di Milano (Italy), where she now teaches archaeometry and ethical issues relating to the archaeological research. She was a team member of the British Mission to Tell al-Amarna and is now a team member of the joint Dutch-Italian Mission to Saqqara of Museo Egizio, Torino and Rijksmuseum van Oudheden, Leiden and of the IFAO-Museo Egizio mission to Deir al-Medina. In parallel, she was the co-director with Prof. Salima Ikram of the North Kharga Oasis Survey and is now the Director of the Italian Mission to Umm al-Dabadib in the Kharga Oasis (Egypt's Western Desert). She received a National Geographic/Waitt Grant and an ERC Consolidator Grant to support her fieldwork in Egypt. She published extensively on the relationship between architecture and mathematics as well as on the exploration of Egypt's Western Desert.

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JEFFREY SPENCER
worked in the British Museum's Department of Egypt and Sudan from 1975 to 2011, the last ten years as Deputy Keeper of the Department. He has a longstanding interest in the mud-brick architecture of ancient Egypt, a topic which was the focus of his postgraduate research at the University of Liverpool, later published in his Brick Architecture in Ancient Egypt (Warminster 1979). He has spent over 40 years excavating town sites in the Nile Valley and Delta, the main activity of which was the identification and delineation of mud brick structures. In addition to numerous publications of these excavations with their record of mud brick tombs, houses and temple foundations, he has also published several articles specifically on the methods of mud brick recognition.

AHMED MAHMOUD TAHER MOHAMED
is co-director of the Centre Franco-Égyptien d'Études de Temples de Karnak (CFEETK) at the Ministry of Tourism and Antiquities. He has extensive experience of countless excavations in Egypt, notably as a team member of CFEETK's. He has been site supervisor of the South Abydos Excavation Early Dynasty Cemetery and Settlement and sectors supervisor of the Sphinx Avenue Excavation, Ministry of Antiquities, Luxor Archaeological Zone. He has also been Instructor in Digital Archaeology in the field of excavations and survey Training Program by the Scientific Center for Archaeological Field Training, as well as Excavation Supervisor in various field schools in Upper Egypt: Ramses II at Abydos (Elbaliana - Sohage), Kom el-Rasras (Kom Ombo-Aswan), Temples of Karnak, Abydos Archaeological Field School Training Program, at Abydos (Elbaliana – Sohage), Qena Archaeological Field School, Dendara Temple, Qena, Deir el-Shalwit Field School (DSFS), Deir el-Shalwit Temple, Luxor-West Bank.

Dendara enclosure wall, Egypt © T. Joffroy

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Above: Western Deffufa at Kerma, Sudan.
© D. Gandreau, 2007
Below: Partial reconstruction of the Augustan enclosure in Medamud,
Louqsor, Egypt. On the foreground, the raïs Gamal Hafes.
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NILE'S EARTH 2023

INTERNATIONAL CONFERENCE

The highly significant and invaluable earthen heritage of the ancient Nile Valley is under increasing threat, specifically as a result of current climate and ecological changes. Thus it is today recognized that specific solutions are needed to effectively preserve the earthen assets present on most Egyptian and Sudanese archaeological sites.

In this context, the ANR Nile's Earth project aims at contributing to this quest by exploring the potential of multidisciplinary approaches for a better identification and knowledge of these earthen archaeological remains, the assessment of their state of conservation, and the definition of adapted and sustainable conservation methods and techniques. The assumption is that, to be relevant, conservation protocols must rely on a thorough knowledge of ancient building techniques and materials, as well as the original building culture.

Being one of the main activities of this project, the Nile's Earth 2023 International Conference aimed at stimulating an international debate towards better characterizing the earthen architecture of the ancient Nile Valley. It also aimed at better identifying needs and exploring relevant methodologies and solutions to meet the growing demand for adequate conservation and enhancement of Egyptian and Sudanese archaeological sites, in accordance with international recommendations.

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